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THESIS

A RECOMMENDED FRAMEWORK FOR THE NETWORK-CENTRIC ACQUISITION PROCESS

by

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September 2009

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13. ABSTRACT (maximum 200 words)

Network-Centric Warfare (NCW) is a theory of war in the information age that hypothesizes that forces, which exploit networked conditions better than their adversaries will achieve tactical advantage. Understanding how Network-Centric Systems (NCS) that support NCW are acquired is essential for the continued development and delivery of systems that are affordable, meet end-user requirements, and that can be fielded quickly.

The Network-Centric Acquisition Process (NCAP) will enable the DoD to deliver NCS that are quickly fielded and that leverage the use of leading-edge technologies.

The NCAP incorporates the systems engineering (SE) approach for system design, and also maximizes the use of industry "best practices." The envisioned NCAP will use, among other things, a central repository of design information (including software, system drawings, etc.) that can be accessed, or pulled, by system development teams .and modified to support specific system needs. The NCAP will use an electronic business (e-Biz) marketplace portal where developers and consumers can be "matched-up" in order to share their products or make needs known, and where NCS evaluations are available for review by interested consumers.

This thesis will clarify network-centric systems acquisition, and explore the benefits that the NCAP would provide.

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A RECOMMENDED FRAMEWORK FOR THE NETWORK-CENTRIC ACQUISITION PROCESS

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LIST OF SYMBOLS, ACRONYMS, AND ABBREVIATIONS

ACAT	Acquisition Category
ADDR	Architecture Development and Risk Reduction
ADM	Acquisition Decision Memorandum
AI	Artificial Intelligence
AIS	Automated Information System
A_{iv}	Information Value Availability
A_{nr}	Net-Ready Availability
AoA	Analysis of Alternatives
API	Application Programming Interface
ASN(NII)/DoD CIO	Assistant Secretary of Defense for Networks and Information Integration/ DoD Chief Information Officer,
ASR	Alternative System Review
BCAD	Business Case Analysis and Development
BCP	Budget Change Proposals
C2	Command and Control
CBA	Capabilities Based Assessment
CDD	Capabilities Development Document
CDR	Critical Design Review
CDT	Capability Development Time
CI	Configuration Item
CJCS	Chairman of the Joint Chiefs of Staff
COI	Condition of Interest
COI	Community of Interest

COTS	Commercial Off-The-Shelf
CPD	Capability Production Document
CTE	Critical Technology Elements
DAB	Defense Acquisition Board
DAMS	Defense Acquisition Management Systems
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DAU	Defense Acquisition University
DIV	Delivered Information Value
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities
DSB	Defense Science Board
DT_i	Initial Estimated Development Time
DT&E	Developmental Test and Evaluation
EMD	Engineering and Manufacturing Development
FCA	Functional Configuration Audit
FRP	Full Rate Production
FRP DR	Full Rate Production Decision Review
FY	Fiscal Year
GFE/S	Government Furnished Equipment/Software
GIG	Global Information Grid
GOTS	Government Off-The-Shelf
GPR	Government Purpose Rights
GWOT	Global War on Terror

HIS	Human Systems Integration
IA	Information Assurance
ICD	Initial Capability Document
IOT&E	Initial Operational Test and Evaluation
IPE	Information Processing Efficiency
IPT	Integrated Product Team or Integrated Project Team
IRS	Internal Revenue Service
ISR	In-Service Review
IT	Information Technology
ITAB	Information Technology Acquisition Board
ITR	Initial Technical Review
JCD	Joint Capabilities Document
JCIDS	Joint Capabilities Integration and Development System
JIC	Joint Integrating Concept
JPG	Joint Programming Guidance
JOC	Joint Operating Concept
JROC	Joint Requirements Oversight Council
KPP	Key Performance Parameters
LCS	Littoral Combat Ship
LCSP	Life-Cycle Sustainment Plan
LRIP	Low-Rate Initial Production
MAIS	Major Automated Information Systems
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MDD	Material Development Decision

MID	Management Initiative Decision
MOE	Measures of Effectiveness
MOP	Measures of Performance
MOSA	Modular Open System Architecture
MSA	Materiel Solution Analysis
M&S	Modeling and Simulation
NCAP	Network-Centric Acquisition Process
NCO	Network Centric Operations
NCS	Network Centric System
NCW	Network Centric Warfare
NPS	Naval Postgraduate School
NSS	National Security System
OMB	Office of Management and Budget
OS	Operations and Support
OSD	Officer of the Secretary of Defense
OTRR	Operational Test Readiness Review
OTS	Off-The-Shelf
OT&E	Operational Test and Evaluation
PBD	Program Budget Decision
PCP	Program Change Proposals
PD	Product and Deployment
PDM	Program Decision Memorandum
PDR	Preliminary Design Review
PEO-IWS	Program Executive Officer of Integrated Warfare Systems
PM	Program Manager

PCA	Physical Configuration Audit
PCDR	Prototype Critical Design Review
PEO-IWS	Program Executive Officer of Integrated Warfare Systems
PPBE	Planning Programming Budgeting and Execution
PPBES	Planning Programming Budgeting and Execution System
PPDR	Prototype Preliminary Design Review
POM	Program Objective Memorandum
PRR	Production Readiness Review
QDR	Quadrennial Defense Review
QoS	Quality of Service
SE	Systems Engineering
SECDEF	Secretary of Defense
SEP	Systems Engineering Plan
SFR	System Functional Review
SHARE	Software Hardware Asset Reuse Enterprise
SPG	Strategic Planning Guidance
SME	Subject Matter Expert
SoS	System-Of-Systems
SRR	System Requirement Review
SVR	System Verification Review
S&T	Science and Technology
TB	Total Bits Processed
TD	Technology development
TDS	Technology Development Strategy
TEMP	Test and Evaluation Master Plan

TRA	Technology Readiness Assessment
TRL	Technology Readiness Levels
TRR	Test Readiness Review
T&E	Test and Evaluation
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force
USC	United States Code
USD(C)	Under Secretary of Defense (Comptroller)
VB	Valued Bits Processed
VIRT	Valued Information at the Right Time
VoS	Value of Service
V&V	Validation and Verification
W_p	Perishability Factor
WWW	World Wide Web
W2COG	World Wide Consortium for the Grid

EXECUTIVE SUMMARY

This thesis will describe the current acquisition of network-centric systems, explore the benefits that a network-centric acquisition process would provide, and provide recommendations on how to improve the acquisition of network-centric systems. It will cover a wide swath of information relating to the network-centric world and will apply it to a very narrow part of network-centric acquisition, specifically introducing and explaining a proposed Network-Centric Acquisition Process (NCAP).

Network-Centricity

Network-Centric Warfare (NCW) is a theory of war in the information age that hypothesizes that forces that exploit networked conditions better than their adversaries will achieve tactical advantage. The Department of Defense (DoD) has been undergoing a transformation in the way it develops and acquires Network-Centric Systems (NCS) that will support NCW. Understanding how NCS is acquired and what affects NCS acquisition is essential for the continued development and delivery of systems that are affordable, that meet user requirements, and that can be fielded quickly.

Department of Defense Acquisition and the Network-Centric Acquisition Process

The DoD desires to field NCS that leverage the use of “leading edge” technologies that are affordable and that meet the warfighter’s needs. The NCAP provides a framework for NCS development and acquisition that ensures that these systems use the most up-to-date-technology. The framework of the NCAP consists of several acquisition and development approaches that, when integrated, provide for quick fielding of NCS with the benefit of frequent, iterative technology upgrades.

Network-Centric Acquisition Process Framework

NCAP uses a Systems Engineering (SE) approach for acquisition. It has metrics for evaluating the effectiveness of the process. NCAP maximizes the reuse of components or use of Off-The-Shelf (OTS) components and uses a data repository to facilitate reuse of components. In addition, NCAP comprises a collaborative

development environment, that stimulates innovation through open source and open license requirements, and creates an electronic business marketplace where consumers and developers can be matched.

The NCAP incorporates best practices from commercial industry in order to create a fast, efficient acquisition process that focuses on delivering “better” speed to “better” capability.

Thesis Conclusions

NCS are very diverse and can range from a large ship to a small unmanned aerial vehicle, but the common thread that makes them network-centric is their ability to harness the power of the network to gain information and decision superiority over an adversary. What allows NCS to harness the power of the network is the backbone of Information Technology (IT) software. The proposed NCAP provides an efficient and effective way to acquire the IT software infrastructure, or network-centric “glue” that enables network-centricity.

The current DoD acquisition system is slow, serial in nature, and delivers large “chunks” of capability at once. The system is expensive, has slow refresh cycles, and virtually ensures that processes and systems are stovepiped. The NCAP provides an alternative for faster acquisition by focusing on delivering “better” speed-to-capability, while incorporating current DoD network-centric guidance and industry best practices.

The NCAP framework incorporates metrics that objectively define “better” and measure the processes ability to deliver “better” speed and “better” capability. The framework also incorporates industry best practices such as component reuse, collaborative environment, open architecture, acquisition data repository, electronic business marketplace, and OTS components.

The implementation of the NCAP will require changes to the existing DoD acquisition processes, including in the way Directives (e.g., DoD Directive 5000.01) are interpreted.

Recommendations

1. Field Test the Network-Centric Acquisition Process

The primary recommendation of this thesis is that the NCAP should be adopted by the DoD for its acquisition of network-centric capabilities. The adoption of the NCAP should be carried out in a small-scale, acquisition environment or prototype venue, and then slowly, and iteratively, scaled to larger acquisitions.

Use NCAP on a small acquisition, be it a test scenario, and then expand if successful acquisitions are achieved.

When implementing the NCAP, it will be important to use the NCAP metrics that measure "better" speed-to-capability, A_{nr} (net-ready availability), and "better" capability, A_{iv} (information value availability) as a means to objectively evaluate the acquisition.

A_{nr} measures the ratio of the Initial Estimated Development Time (DT_i) over the Capability Development Time (CDT) and can be seen in Equation (1).

Equation (1): $A_{nr}=DT/CDT$, where $CDT=(DT_c+ TT_c +CT_c)$

A_{iv} is the product of the Information Processing Efficiency (IPE) and the Delivered Information Value (DIV) and can be seen in Equation (2).

Equation (2): $A_{iv}= IPE \times DIV$

NCAP framework will likely not be immediately fully operational (i.e. data repository, e-Biz marketplace, or development environment working), but this should not slow or halt the implementation of the NCAP. As NCAP framework items become operational, they should be incorporated into the operational version of the NCAP.

2. Change the Operation of the Defense Acquisition System, DoD Directive 5000.01

DoD should implement the recommendations of the Defense Science Board (DSB) March 2009 report, *Department of Defense Policies and Procedures for the Acquisition of Information Technology*.

By implementing the DSB recommendations, the DoD will give the NCAP an acquisition framework that will enable fast, iterative, and agile acquisition.

3. Create a Network-Centric Data Repository

The DoD should begin creating a network-centric data repository that employs the search and ontology structures of a data repository as described in the report: *Ontology-based Solutions for Software Reuse*.

The creation of the data repository should begin slowly and on a small scale, and will be a challenging and difficult task. It will require clear and well thought-out guidance on how to enter, classify, and store repository items. The network-centric data repository may not be operational until several iterations of the NCAP are complete.

4. Framework of Network-Centric Collaborative Development Environment

DoD should conduct further studies to determine the best framework to use in the network-centric collaborative development environment. The framework will include the development environment to use, the standard software interfaces, the minimum IA requirements, and the licensing rights requirements.

Forge.mil should serve as a model, prototype, or even as the development environment to be used when implementing the early versions of the NCAP.

5. Electronic Business Marketplace Structure and Business Rules

DoD should conduct further studies to determine the best framework to use in the electronic business (e-Biz) marketplace. Although the requirements for the e-Biz marketplace were discussed in this thesis, consultation and collaboration with e-Biz marketplace industry leaders (eBay and Amazon) could help create an effective DoD e-Biz marketplace, or prototype, on which to test the NCAP.

6. Network-Centric Acquisition Stakeholder Education and Training

DoD should use the material in this thesis to create a course that would help educate DoD acquisition stakeholders on network-centricity, the DoD acquisition process, and the NCAP.

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Writing a thesis is tough, but putting the final finishing touches on it is a bittersweet way to complete a wonderful learning experience.

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I. INTRODUCTION

Network-Centric Warfare is a theory of war in the information age, which hypothesizes that forces that exploit networked conditions better than their adversaries, will achieve tactical advantage [1]. The Department of Defense (DoD) has been attempting to transform the way it develops and acquires network-centric systems (NCS) that support network-centric warfare (NCW). Understanding how NCS are acquired is essential for the continued development and delivery of systems that are affordable, meet end-user requirements, and that can be quickly fielded.

The DoD seeks to deliver NCS that are quickly fielded, and that leverage the use of leading-edge technologies. The proposed network-centric acquisition process (NCAP) is an enabler for fast, efficient, and effective NCS development. Using the NCAP, NCS would "ride" the technology wave[1], have fast development and certification, and rely on frequent, iterative technology upgrades.

The NCAP incorporates the Systems Engineering (SE) approach for system design, and also maximizes the use of industry "best practices" such as maximizing the reuse of software and subsystems. The envisioned NCAP will use, among other things, a central repository of design information (including software, system architecture drawings, etc.) that can be accessed, or pulled, by system development teams, and modified to support specific system needs. The NCAP will use an electronic business (e-Biz) marketplace portal where developers and consumers can be "matched-up" in order to share their products or make needs known, and where NCS evaluations are available for review by interested DoD consumers.

The Defense Acquisition System (DAS) is a complex system that receives inputs from many organizations, groups, and stakeholders and whose output is controlled by the

[1] "Ride" the technology wave refers to NCS taking timely advantage of technological advances in order to incorporate them into the design and deliver advanced technology to the stakeholders. This helps ensure that new fielded technology is not obsolete.

actions of other, sometimes very different, organizations, groups, or stakeholders. The DAS goal is to acquire, field, and maintain (life-cycle) a product, or system, that fulfills an identified capability need [2].

Developing and choosing the "best" product is often a daunting task because many decisions must be made to determine if a new system is needed or if an existing system meets the requirements, or if modifications to an existing system will be required. The decision "trade space" has many external pressures that help the DAS develop the acquisition decision. Ironically, these pressures tend to produce inefficiencies, or sub-optimization, of the very systems being developed or acquired.

SE has been an integral part of defense acquisition for many years. The use of SE processes allows for the development of systems where the "end-user's" requirements are effectively elicited and efficiently decomposed into sub-systems that can easily be integrated into a valuable and useful product.

A thorough understanding of how the DAS operates, and the impact of the use of SE processes, will benefit all acquisition process stakeholders. The way DoD acquires NCS will be influenced, and changed, after acquisition stakeholders realize the benefits that the NCAP will have on NCS acquisition.

This thesis will explain network-centric systems acquisition, network-centric acquisition, provide metrics to describe new NCAP models, and explore the benefits that the NCAP would provide.

A. BENEFITS OF THE THESIS STUDY

The thesis study benefits the DoD acquisition community because it will introduce a revolutionary method for the acquisition of network-centric capabilities by the DoD. The foundations of the NCAP incorporate industry best practices, SE principles, and are a paradigm shift toward achieving better speed to better capability.

In addition, the original purpose of this thesis was to create the framework for network-centric systems engineering course material for Naval Postgraduate School (NPS) network-centric SE students. Therefore, along with assisting the DoD acquisition community, this thesis will assist in network-centric systems engineering education.

B. THESIS OVERVIEW

The focus of this thesis is a process by which the DoD can begin acquiring NCS efficiently and cost effectively, specifically the NCAP.

To best describe the NCAP, it is crucial to understand what network-centricity entails and what NCS are. Chapter II of this thesis is devoted to explaining network-centricity. It describes the origins of NCW, explains the theory on which it was based, gives current DoD instantiations of NCS, and finishes by defining NCS.

Chapter III gives an overview of Defense Acquisition by giving a detailed explanation of the Planning Programming Budgeting and Execution System (PPBES), the Joint Capabilities Integration and Development System (JCIDS), and the DAS.

Chapter IV discusses the SE approach to acquisition. It gives an overview of SE processes, and then maps a generic SE approach to acquisition to the DoD acquisition process[2].

With a foundation on NCS, DAS, and SE (in previous chapters), Chapter V presents the NCAP. It gives a description of the NCAP, presents metrics to measure network-centric acquisition, describes the framework of NCAP[3], and discusses a new network-centric acquisition model[4].

Chapter VI summarizes Chapters I–V and presents conclusions and recommendations.

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[2] The DoD acquisition process as described by DoD Directive 5000.01 [3].

[3] The NCAP framework includes component reuse, collaborative development environment, data repository, electronic business marketplace, use of off-the-shelf components, and open systems and open licensing rights.

[4] This is an acquisition model recommended by the Defense Science Board to replace the model used in DoD Directive 5000.01 [3] and discussed in Chapter V.

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II. NETWORK-CENTRICITY

A. OVERVIEW

This chapter will lay the groundwork for the thesis by describing Network-Centric Operations (NCO), Network-Centric Warfare (NCW), Network-Centric Systems (NCS) and by discussing the origins of NCW. NCW is a driver for change in the way modern militaries operate and by understanding NCW it is easier to understand the purpose of NCS.

The basic premise of network-centricity stems from the theory that when warfighting forces are networked, and understand how to exploit the "network terrain," they can develop an informational "tactical advantage."[5] This only holds true when the networked information and data flow are optimized and the warfighters do not suffer from information overload. Situational awareness allows for Blue Forces to achieve decision superiority and dominant maneuver[6] over their adversaries.

In this chapter, NCW's central tenets and their relevancy in the transformation of how military forces operate will be discussed. Metcalfe's law will also be presented to show the advantages of having networked forces, followed by a discussion of current network-centricity and the World Wide Web (WWW).

The Global Information Grid's (GIG) origins will be discussed, as well as a brief description of each DoD Department's complementary instantiations of the GIG, and the GIG's role as an enabler of NCW.

Finally, this chapter will examine what is required for the DoD to transform into a network-centric enterprise, in light of observations that have emerged since the DoD conceived NCW.

[5] NCW literature has evolved to recognize that adversaries will certainly be networked. The issue becomes taking better advantage of the network than one's adversary [4] [5].

[6] Decision superiority, dominant maneuver, and the central tenets of NCW will be discussed later in this Chapter, but all stem from the writings of Cebrowski and Garstka [6].

B. NETWORK-CENTRIC WARFARE

NCW has many definitions, but the first definition to be presented was originally discussed by Vice Admiral Arthur Cebrowski and John Garstka in their 1998 article "Network-Centric Warfare: Its Origins and Future"[7]. According to Cebrowski:

> [NCW] and all of its associated revolutions in military affairs grow out of and draw their power from the fundamental changes in American society. These changes have been dominated by the co-evolution of economics, information technology, and business processes and organizations, and they are linked by three themes:
>
> - The shift in focus from the platform to the network
> - The shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem
> - The importance of making strategic choices to adapt or even survive in such changing ecosystems. [6]

In Cebrowski's definition, he talks about the shift from "the platform" to "the network," and what he is implying is the shift from "platform-centric" to "network-centric" operation. Simply stated, this means that when a single platform, or multiple platforms are networked together, the performance of the combined force is improved. This is achieved because networked forces have access to more information, wider information reach, and richer information.

According to John Garstka,

> NCO are military operations that are enabled by the networking of the force. NCO provide a force with access to a new, previously unreachable region of the information domain. The ability to operate in this region provides warfighters with a new type of information advantage, an advantage broadly characterized by significantly improved capabilities for sharing and accessing information.
>
> NCW enables warfighters to leverage this information advantage to dramatically increase combat power through self-synchronization and other network-centric operations. [8]

Self-synchronization is achieved by the collectively shared situational awareness and refers to the warfighter, or warfighting unit's ability to continue executing their assigned mission even if the top layers of command are lost or disconnected from the network. According to a Naval War College report,

> Self-synchronization facilitates speed of command, the process by which forces use information superiority to lock-in success while locking-out enemy strategies … In summary, self-synchronization will allow forces, empowered by good situational awareness, to recognize and act on a situation without further direction. [9]

The central tenets of NCW are:

- a robustly networked force improves information sharing
- information sharing and collaboration enhances the quality of information and shared situational awareness
- shared situational awareness enables collaboration and self-synchronization and enhances sustainability and speed of command
- the above , in turn, results in dramatically increased mission effectiveness.

The central hypothesis of NCW is that a force with these capabilities can increase combat power by better synchronizing effects in the battlespace, achieving greater speed of command, and increasing lethality, survivability, and responsiveness [10].

The link between information domain, information superiority, decision superiority, dominant maneuver, different NCW domains, and NCW will be explained in the following four sub-sections.

1. Information Domain and Information Superiority

Information domain is the domain where information is created, manipulated, and shared. As an example, military Command and Control (C2), warfighter coordination and commander's military intent all reside in the information domain [8].

Information superiority is a condition of the information domain that is achieved when a warfighter has an information advantage over an adversary. It can, therefore, be stipulated that a networked force, consisting of several platforms, will have informational superiority over a non-networked force. Figure 1 shows how two military aircraft, when

networked, even though through a tactical link[7], are capable of achieving informational superiority over a non-networked adversary by an increase in information “richness” and “reach.” This information superiority allows them to operate in the “network-centric” region of the information domain, as opposed to the “platform-centric” region.

According to a DoD report to Congress,

> [NCW] allows the force to achieve an asymmetric information advantage. This information advantage is achieved, to a large extent, by allowing the force access to a previously unreachable region of the information domain − the network-centric region − that is broadly characterized by both increased information richness and increased information reach. [11]

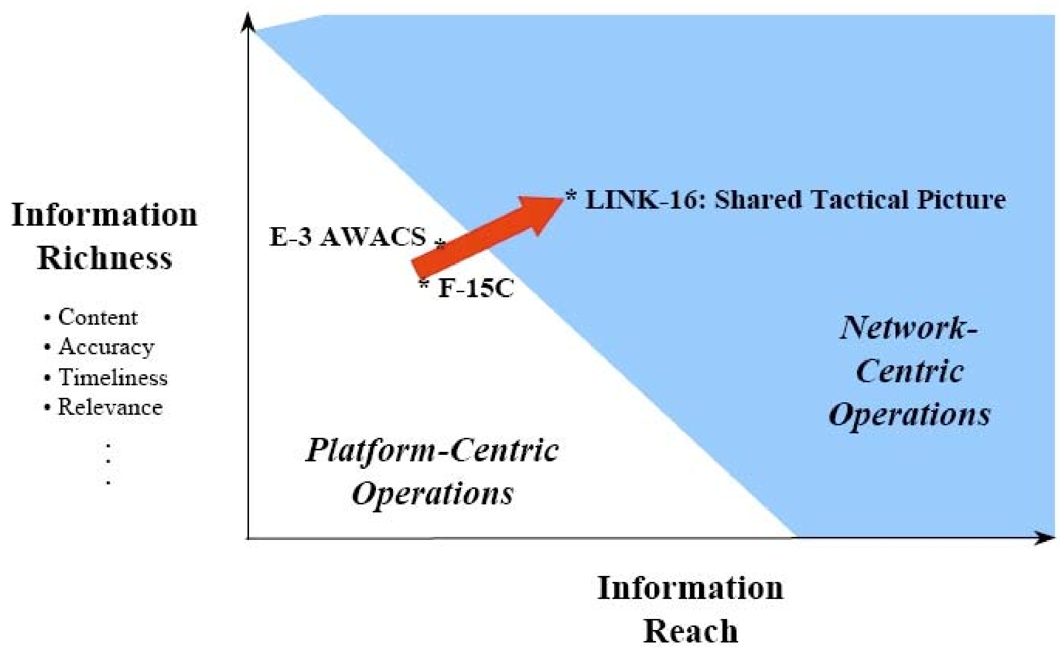

Figure 1. Information Domain and Effects of Networked Forces (From [11])

NCW’s advantage is built upon improved capabilities for information sharing and networking that when coupled with improved sensing capabilities can enable a force to realize dominance over its adversary.

7 These aircraft were “networked” via a tactical link. Tactical links are serial point-to-point connections governed by strict circuit discipline. In the 21st century the term “network” usually implies a many-to-many “cloud” with no circuit discipline whatsoever.

2. Decision Superiority

Informational advantage is achieved when platforms are networked, which gives warfighting commanders a competitive advantage over their adversaries. Commanders and their forces are thus able to make better decisions that can be implemented faster than the adversary can react. This is referred to as "decision superiority," and it provides significantly enhanced situational awareness to not only the commander, but to the entire force [11].

Take the operational example of an air-to-air mission that follows. Advocates of NCW claim that network-enabled information sharing provided aircrews with enhanced situational awareness and allowed them to fight smarter and make better decisions faster and therefore win more decisively. However, there are some caveats. By contrast, network-centric theory typically considers "networks" to be many-to-many networks with unconstrained data flow. Therefore, while this example clearly illustrates the power of decision superiority, it is not clear that superiority resulted from "network enablement" or from disciplined information exchange and command and control (C2) (preventing information overload enables decision superiority).

An operational special project conducted by the United States Air Force (USAF) in the 1990s demonstrated how pilots flying F-15Cs equipped with tactical data links could double mission effectiveness (measured in kill ratios). Across a broad spectrum of engagement scenarios, day/night and ranging from one-on-one to eight vs. sixteen, the combination of information and decision-making advantages resulted in a 2.6-fold increase in kill ratios. [11]

3. Dominant Maneuver

Dominant maneuver is the ability of networked forces to gain positional advantage over its adversary with speed and a high operational tempo in the achievement of assigned military tasks. NCW capabilities can support dominant maneuver by enabling:

- Adaptive and concurrent planning
- Coordination of dispersed units

- Status updates of subordinate units
- Roadmap to mission accomplishment [11]

A military commander who can achieve dominant maneuver attains a positional advantage, that, when combined with decisive combat power, can compel his adversary to react from a position of weakness—effectively giving control of the battlespace at a time of the commander's choosing.

4. Network-centric Warfare Domains

Effective NCW requires the networking of the three domains of warfare. Figure 2 depicts the three domains:

- Physical domain
- Cognitive domain
- Information domain[11]

a. Physical Domain

The physical domain consists of the place where military influence is desired. This domain is where platforms interact and where networks connect them. Military forces strike, maneuver, and protect the physical domain.

b. Information Domain

As defined previously in paragraph B.1, the information domain is where information resides. It is created, shared, and manipulated by its users.

c. Cognitive Domain

This domain is in the minds of the warfighters. The cognitive domain is shaped by human perception and nurtured by the information and data supplied by the information domain. It is the most difficult to predict and understand and therefore is where the personal experience and training of the warfighters can either lift or let settle Sun Tzu's "fog of war"[12]. Situational understanding, awareness, and assessment are developed in the cognitive domain.

These three domains, when properly networked, can enable NCW to occur at its most mature form, where:

- The physical domain is seamlessly connected,
- The information domain allows for efficient collection, sharing, and access to information allowing the warfighting force to achieve informational advantage over the adversary, and
- The cognitive domain allows for shared high quality of situational awareness and the ability to self-synchronize. [11]

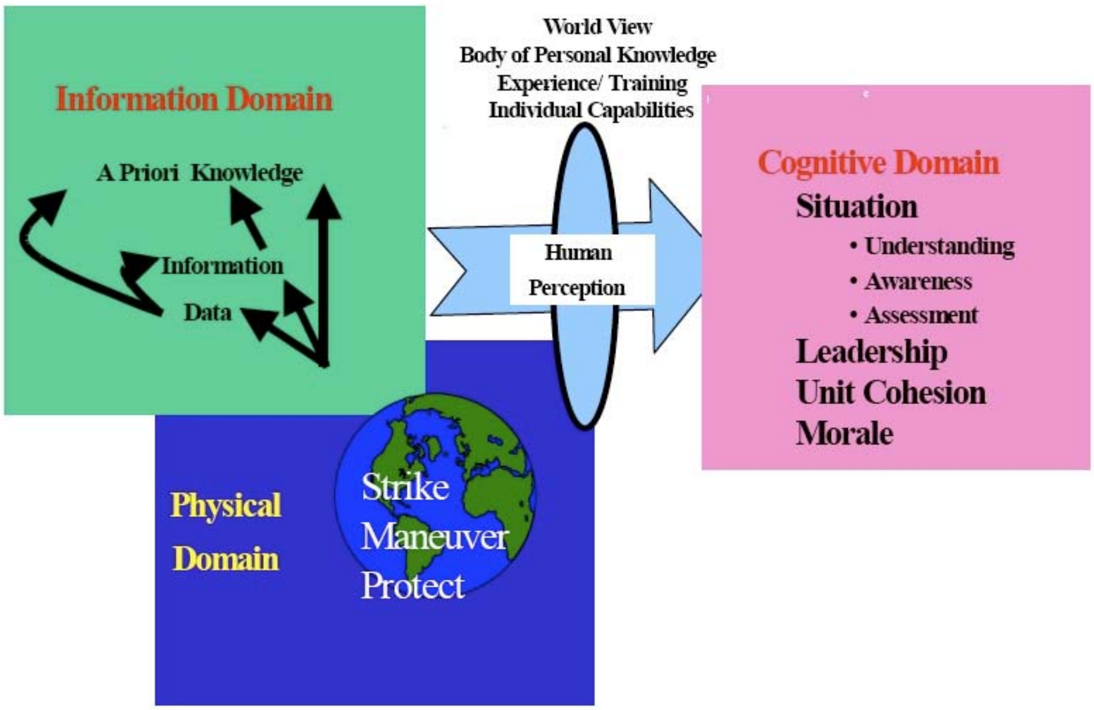

Figure 2. Domains of Warfare (From [11])

Having defined the different aspects of NCW (information superiority, decision superiority, dominant maneuver, and NCW domains) the underlying theory of network-centricity will be presented in the next section.

C. METCALFE'S LAW

NCW advocates the use of Metcalfe's law to explain the claim that a networked force has an advantage over a non-networked force because of the potential value of a network. According to Metcalfe (see Figure 3), as the number of nodes in a network increases linearly, while the potential "value" or "effectiveness" of the network increases quadratically[8]. Figure 3 shows how "networked" nodes are more powerful or effective when compared to the linear behavior of non-networked nodes.

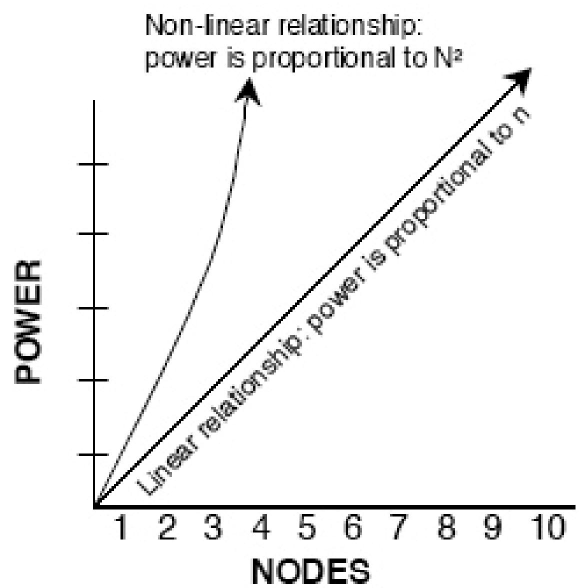

Figure 3. Metcalfe's Law (From [13])

Figure 4 portrays a superior information position relative to a competitor (or adversary) in military operations. The three dimensions on the graph are percentage of relevance, accuracy, and timeliness. As 100% relevance, accuracy and timeliness is reached in each axis, the upper limit of the information domain is reached. The "Blue" and "Red" forces[9] are equivalent, or evenly matched, with the exception that the "Blue" force is network-centric. The network enables information intensive interactions between nodes, giving the "Blue" force an advantage over the "Red" force.

[8] For every "N" node in a network, there are "N-1" potential interactions between the nodes. In a network of "N" nodes, the total number of potential interactions is: $N*(N-1)$, or N^2-N. Thus, for large values of N, the NCW theory claims that the "power" or "effectiveness" is proportional to N^2 [13].

[9] "Blue" and "Red" forces are respectively synonymous with allies and adversaries.

In the twentieth century, network-centric ideas were profound because they predicted the advances that networking forces would provide. In the twenty-first century, they have become self-evident. Consider the network-centric power the WWW provides. Armed with a search engine, anyone with the ability to get on the Internet can tap billions of data sources instantly and find more and more useful information than someone off line. Indeed, many enterprises from the world of e-commerce (e.g., iPhone) to the world of e-Gov (e.g., eFile tax return services) have leveraged network-centricity to their advantage. With respect to NCW, clearly if Blue Forces were "on-line" and Red Forces were not, Blue Forces would have instant information superiority because of the advantage of being networked with a larger domain of nodes[10].

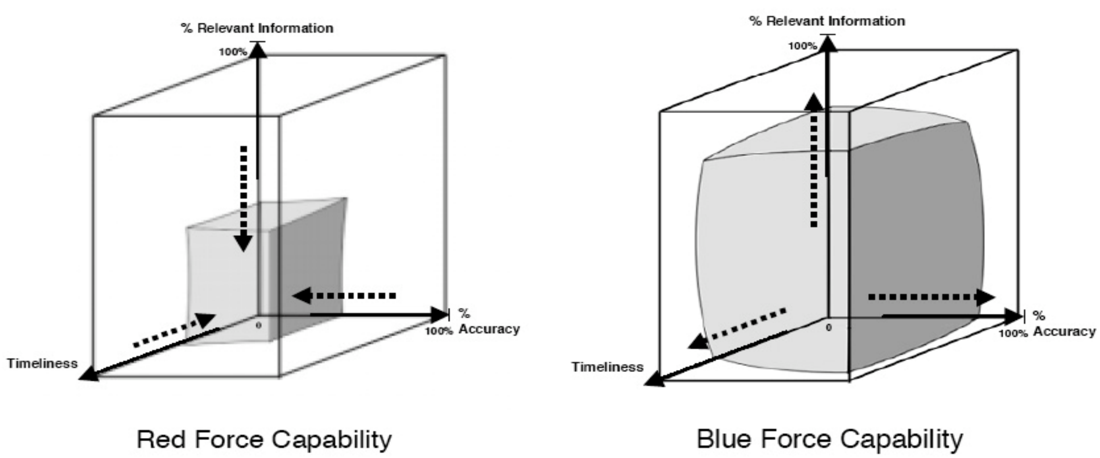

Figure 4. Superior Information Position Vis-à-vis an Adversary due to Network-Centricity (From [13])

Unfortunately for Blue Force, it is hard to imagine an adversary that does not have access to the WWW. On the contrary, today's Red Force (e.g. Al Qaeda) has better access to "the network," the WWW, than U.S. Blue Forces who are constrained by ultra-restrictive security policies [14] to operate on private military networks with far fewer nodes than the WWW. Clearly, an approach that compares the advantage a networked

[10] This argument assumes that the information that the Blue Forces want is available on the WWW.

Blue Force has over a non-networked Red Force is no longer relevant. Likewise, recent history proves that any relevant approach to evaluating the effectiveness of NCW must acknowledge that both Blue and Red Forces may not be traditional military actors.

Twenty-first century experience has also revealed a scale issue associated with the Metcalfe's Law argument. Access to billions of nodes across a network can easily lead to information overload, or in other words, make it difficult to find just the right piece of information in time to enable a critical decision, i.e. achieve information superiority.

Therefore, in today's environment, adversaries will certainly have equal or better access to networks of data providers on the one hand. On the other hand, access to too much unfiltered information is counterproductive. Hence, Blue Force might re-think the original NCW premise that the mere availability of more data across a network is equivalent to "value" and/or "effectiveness" [15]. The future NCS, of multi-node networks, will require automation of information extraction through the use of Artificial Intelligence (AI) systems. It is through the automation of information extraction, that warfighters can gain information superiority over their adversaries.

D. THE GLOBAL INFORMATION GRID AS A NETWORK-CENTRIC WARFARE ENABLER

Joint Vision 2020 highlights the importance of achieving improved capabilities for operating in the information domain, and the DoD solution is the GIG. According to Joint Vision 2020, the GIG is:

> …the globally interconnected, end to end set of information capabilities, associated processes, and people to manage and provide information on demand to warfighters, policy makers, and support personnel. [16]

DoD intends the GIG to be the keystone that will help enable both NCW and NCO because of improved information sharing—better information, more of it, and faster sharing—amongst all stakeholders, and will lead to improved situational awareness. The GIG's success will depend on its ability to achieve fully interoperable and interconnected forces, a daunting task that is made ever more difficult because of large number of legacy systems that aren't able to be interconnected.

The GIG hopes to enable information sharing that will provide commanders with improved capabilities for C2, for formulating and disseminating commander's intent based on up-to-date situational awareness, and enable the warfighting force to be more dispersed, survivable, agile and smaller.

The role of the GIG in enabling NCW, Information Superiority, and ultimately full spectrum dominance is portrayed in Figure 5. The vision for the GIG is that it will dramatically improve information sharing capabilities by leveraging cutting-edge information technology to create a network-centric information environment.

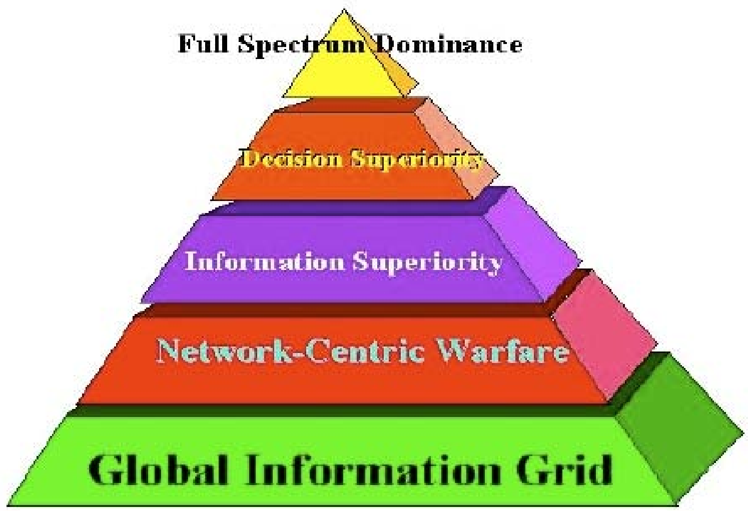

Figure 5. The GIG as an Enabler (From [11])

NCW intends to revolutionize the way we conduct warfare and the GIG is the "transformation initiative" that will provide the infrastructure required to network the forces [11]. In the final analysis, the GIG is all about enabling the flow of information.

The next four sub-sections will discuss the origins of the GIG, and how FORCEnet, LandWarNet, and ConstellationNet all relate to the GIG.

1. Origins of the Global Information Grid

The concept of a "Global Information Grid" was borne out of concerns regarding interoperability and end-to-end integration of Automated Information Systems (AIS)[11]. The primary function of the GIG is to support and enable DoD missions, functions, and operations [18]. The future GIG will be a System-Of-Systems (SoS)[12] that provides a set of value-added functions operating in a global context to support processing, storage, and transport of information.

The current version of the GIG is not fully networked, because it is made of many smaller networks that have not been (and may not be able to be) networked together. Parts of the GIG have many stovepipe systems, with varying degrees of interoperability, and whose access to needed information is constrained. Through a series of capability increments, Figure 6 shows how the target GIG's architectural vision will be achieved through a federated[13] approach that will ensure coherent transition to the target GIG [18].

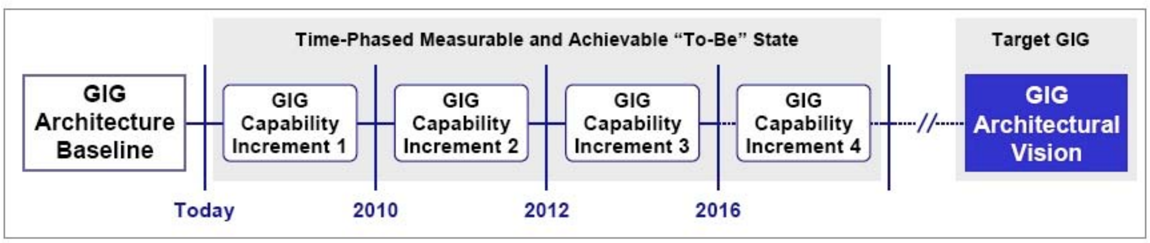

Figure 6. Transformation to "Target GIG" (From [18])

2. FORCEnet and the GIG

According to Rear Admiral Rodriguez, the Chief Engineer for the Space and Naval Warfare Systems Command (SPAWAR) from 2004 to 2008, "FORCEnet is the Navy's instantiation of the [DoD] GIG" [19]. Rodriguez went on to explain that if the

[11] AIS refers to an assembly of computer hardware, software, firmware, or any combination of these, configured to accomplish specific information-handling operations [17].

[12] An SoS is "a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities" [2].

[13] Federated, in this context, refers to how the GIG will be networked and viewed as a whole entity by its users, and vice separate interconnected networks.

GIG were the federal highway system, which connects all the military departments, then FORCEnet would be infrastructure that connects that Department of the Navy's "roads" to the GIG. The users of the transportation system (the GIG) would use the same signal and signs (common architecture) to allow for interoperability.

According to the Naval Network Warfare Command, their definition of FORCEnet is:

> The operational construct and architectural framework for Naval Warfare in the Information Age, to integrate WARRIORS, sensors, networks, [C2], platforms, and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space and sea to land… The future implementation of Network Centric Warfare in the naval services. [20]

3. LandWarNet and the GIG

According to an information paper published with the **2008 Army Posture Statement**, [21] "LandWarNet is the Army's portion of the GIG [22]." LandWarNet consists of infrastructure and services that move information through the Army's network. It enables the "management and use of warfighting and business information." [22]

LandWarNet will be the enabler, in conjunction with the GIG, for the Army's achievement of decision superiority and ultimately full spectrum dominance. It will deliver to the warfighter voice, data, and video at the tip of the tactical edge, with the goal extending these capabilities to the lowest levels of the Army's modular force [22].

4. C2 Constellation, ConstellationNet and the GIG

C2 Constellation is the Air Force's solution to the GIG [23] [24] and will provide war fighters access to a globally distributed common knowledge base of shared information, providing a consistent level of understanding and situational awareness between all war fighting elements [25]. ConstellationNet is the communications network—air, space, and terrestrial—that will allow a free flow of information that is accessible and presented to warfighters at the right time and right place to achieve the commander's desired effects.

E. THE GLOBAL INFORMATION GRID AND FORCE EXECUTION

As previously stated, the GIG hopes to be the foundation with which NCW's full spectrum dominance can be achieved. A GIG enabled network-centric force can utilize the networks and its processes to achieve full spectrum dominance as forces execute their missions. Figure 7 shows how the GIG connects the network-centric forces, facilitates the acquisition of information superiority that is used to make C2 decisions, and allows forces to be utilized with the goal of achieving full spectrum dominance.

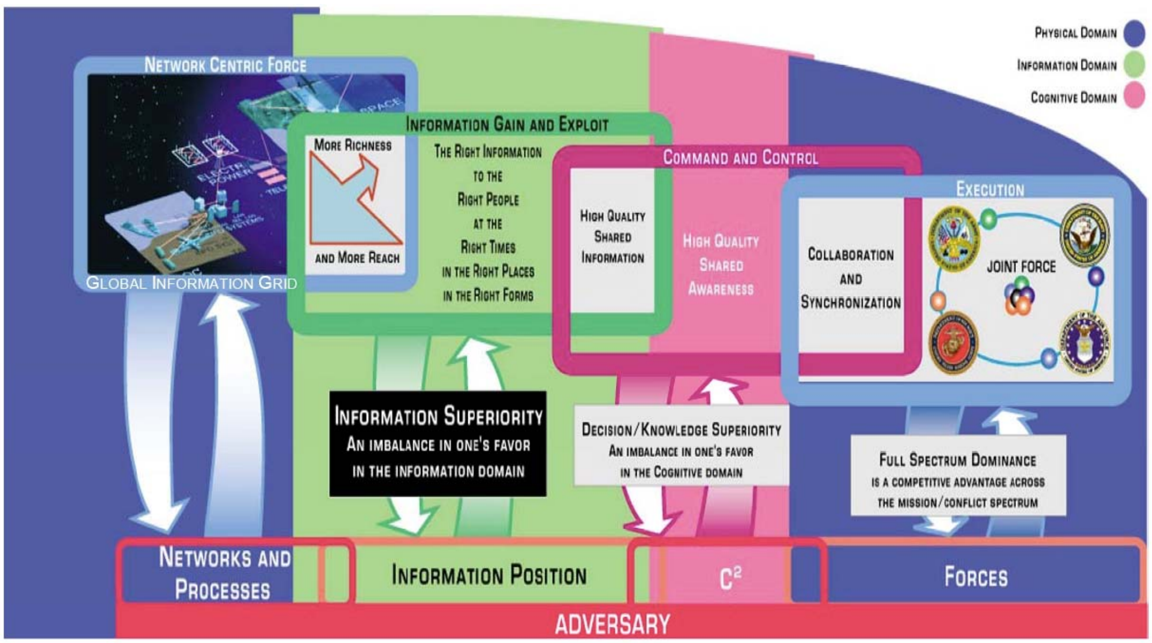

Figure 7. Impact of the GIG on NCW (From [11])

Information sharing, in a networked environment, enables the network-centric forces to gain and exploit information—the right information, to the right people, at the right time, and in the right form. Exploiting information correctly gives the network-centric-forces information superiority, a situation where there is an imbalance in their favor in the information domain. With information superiority, the force commander can influence his C2 by fusing high quality shared information with shared awareness and enabling the forces' collaboration and synchronization. This culminates in the ability of the forces to achieve full spectrum dominance—a competitive advantage across the mission spectrum—in the execution of their tasking.

F. NETWORK-CENTRIC SYSTEMS AND NETWORK-CENTRIC SYSTEMS ENGINEERING CORE

Network-Centric Systems (NCS) support the concepts presented in this chapter. NCS are networked systems that enable warfighters to gain decision superiority over their adversaries—better information, faster, and thus allowing quicker reaction.

An important key attribute of NCS is its ability to deliver valuable information to the end-user. Having too much information causes information overload, so network-centricity advocates the delivery of Valued Information at the Right Time (VIRT). Professor Rick Hayes-Roth defines VIRT as follows:

> VIRT is a generic solution to the problem of how to assure that important information is passed along and unimportant data is not. The technology can be implemented across diverse deployment platforms to meet specific requirements. In its most simple configuration a VIRT appliance consists of an intelligent monitor that continually examines and interprets data sources for Condition Of Interest (COI) events and a condition alerter that transmits important events promptly to concerned parties using their preferred channels and styles. [26]

As the DoD transitions toward network-centricity, the systems and SoS that are network-centric will collaborate to give the network-centric users the informational superiority that will lead to decision superiority and ultimately to full spectrum dominance of the adversary. During the network-centric transition, non-NCS will require upgrades to make them network capable and allow them to achieve some limited form network-centricity.

The Network-Centric Systems Engineering (NCSE) core is presented to give a background on NCS. Figure 8 is the NCSE core diagram. The NCSE core can be thought of as a SoS that is made up of four approaches and a core that unites the four approaches using communication/networking fundamentals [27]. The four approaches in the NCSE core diagram are:

- Top-down approach of Net-Centric Enterprise Services and Service Oriented Architectures (including Communities Of Interest (COI), Collaboration, Security, Information Assurance (IA), Discovery, etc.)

- Bottom-up approach of smart distributed systems, such as smart sensor networks, mobile wireless ad-hoc networks, sensor fusion and artificial intelligence
- Middle approach of smart push(publish)/smart pull(subscribe)
- Side view approach of a disadvantaged user (communications to the tactical edge—whether their communications are limited by choice, have limited communications capabilities, and/or lack the appropriate security levels to communicate, but overall has a need to push/pull information/services)

These four approaches are integrated, or brought together, by fundamentals of networking, communications, distributed computing, and real-time processing. Figure 8 depicts a tree with four branches symbolizing the network-centric approaches, and the trunk symbolizing the integration of these four approaches into a generic NCS.

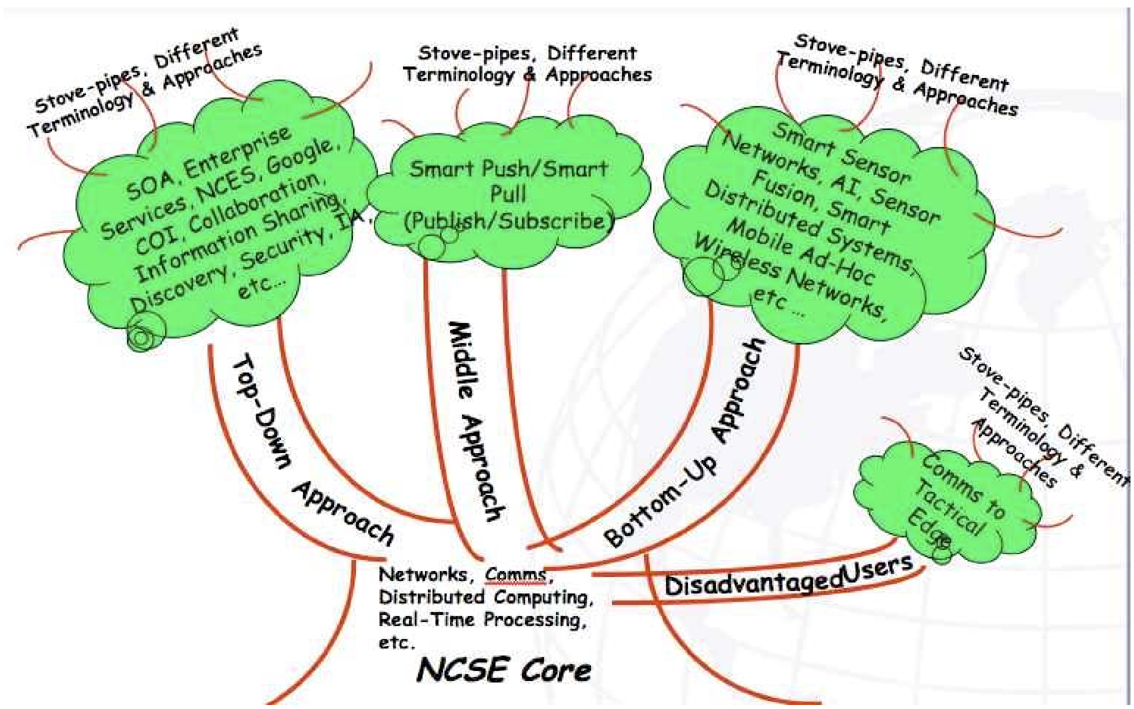

Figure 8. Network Centric Systems Engineering Core (From [27])

A generic NCS has all four branches and the trunk is networked together in such a way that the top-down sub-system is able to share stored information for the NCS to operate. In addition, this generic NCS is able to take organic data and use the bottom-up approach to share it with other NCS. The middle approach is what allows the top-down

and bottom-up approaches to effectively pass information throughout the network using smart pull/push and AI. The trunk of the NCSE is the shared "backbone" on which the branches are integrated.

The NCSE core will be discussed again in Chapter V, when it is used to depict a generic view of the NCAP.

G. CONCLUSION

This chapter discussed NCW, its origins, and how the DoD has shifted to embrace and implement the network-centric environment.

Also discussed was how the information domain is changed when forces are networked—network centric vice platform centric. Networking forces, platforms, or capabilities gives warfighters informational and decisional superiority, which enables them to maneuver dominantly over an adversary.

With regard to NCW, the three domains of NCW were presented, which when properly networked, would lead to a mature form of NCW where the forces are seamlessly connected and have high situational awareness and the ability to self-synchronize. Metcalfe's law was presented to explain how an increase in the number of network nodes impacts force effectiveness.

The GIG was discussed regarding how it will be the foundation on which NCW will be built, with the goal of achieving full spectrum dominance in the battlefield (actual or virtual[14]). Although the GIG is one of many NCS, it is the model through which all other NCS will be networked. NCS were discussed from the view of military services and a NCSE core.

The recent DoD transformation has been based upon the development and/or acquisition of NCS by the DoD, with the focused goal of enabling the network-centric

[14] Virtual battlefield refers to battles waged on the WWW (cyber-warfare or dispersed command and control engagements.

fighter in NCW and NCO. President Bush alluded to his commitment to network-centric transformation during his remarks at the U.S. Naval Academy Commencement on May 25, 2001, when he stated:

> We must build forces that draw upon the revolutionary advances in the technology of war that will allow us to keep the peace by redefining war on our terms. I'm committed to building a future force that is defined less by size and more by mobility and swiftness, one that is easier to deploy and sustain, one that relies more heavily on stealth, precision weaponry and information technologies. [11]

Although, President Bush's remarks do not specifically say "network-centric," the context of the speech implied that NCS will allow forces to be smaller, quicker, and self-synchronous.

In NCW, the goal is to create a network-centric force that can share and exchange information amongst geographically separated units of the warfighting force, regardless of platform, service, command structure, or location. As Garstka stated, "a network-centric force is an interoperable force, a force that has global access to assured information, whenever and wherever needed" [8].

Given the minimal progress of the DoD toward its network-centric goals over the last decade, it is perhaps time to re-evaluate the network-centric transformation approach[15].

After an overview of network-centricity presented in this Chapter, Chapter III will give an overview of DoD acquisition, detailing the PPBES, the JCIDS, and the DAS. Chapter IV will present SE approach and explain how the SE approach can be mapped into the DAS. Network-centricity is the foundation for the acquisition process to be discussed in Chapter V.

The discussions in this chapter and Chapters III and IV will give the reader the required foundation to discuss network-centric as an acquisition process.

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15 Network-centric transformation approach includes the DoD efforts to become network-centric and includes all the efforts it has taken to do so.

III. DEPARTMENT OF DEFENSE ACQUISITION OVERVIEW

A. OVERVIEW

In order to understand network-centric acquisition, a background in DoD acquisition is needed. This chapter will explain how the DoD acquisition system operates. System acquisition is a complex and iterative process that takes a long time to complete and requires the interaction of many dispersed stakeholders. The DoD acquisition system, also called Big "A" acquisition process in Figure 9, is comprised of the following:

- Planning Programming Budgeting and Execution System (PPBES);
- The Joint Capabilities Integration and Development System (JCIDS);
- The DoD 5000.2 Acquisition Process, also know as the Little "a" acquisition process.

The interaction between these three processes is fraught with tensions[16] that create inefficiencies in the acquisition of DoD systems. This chapter will present the different stakeholders of the DoD acquisition process and explain how they directly impact the acquisition process [2].

Together, the three parts of the DoD acquisition system provide an integrated approach to strategic planning, identification of needs for military capabilities, systems acquisition, and program and budget development [2].

B. DEPARTMENT OF DEFENSE ACQUISITION

Acquisition of programs/systems the DoD needs in order to conduct its missions is extremely complex and requires the carful balance of many diverging views, interests, needs, and directives.

[16] The tensions between the processes range from budgetary (Congressional budget process, acquisition cost overruns), to determining what the warfighter needs (capability gaps determination).

At a high level, Figure 9, shows the three overlapping processes that make up the DoD's acquisition system. These processes were intended to work together to help acquire the "best" system/product for the DoD, but in reality, effective coordination and interaction between the processes is necessary for successful acquisition to occur.

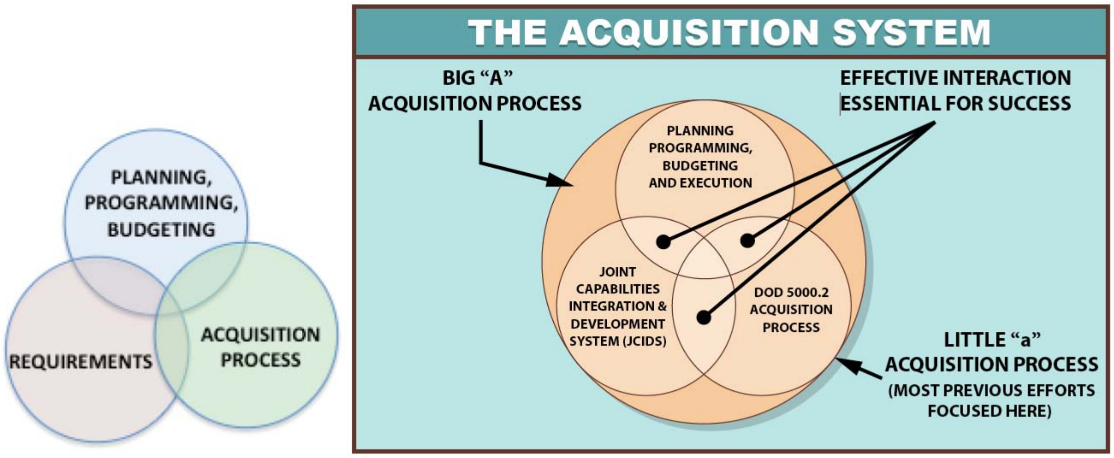

Figure 9. Two views of the DoD Acquisition System (From [28],[29])

In Figure 9, the interaction of these processes is where competing interests are amplified, which introduce inefficiencies into the entire "Big A" acquisition process.

A successful acquisition is described as a system or service whose acquisition provides the needed capabilities, at the estimated cost (or with acceptable cost growth), and that is delivered in a timely manner.

The next few sub-sections will discuss the PPBES, the JCIDS, the DoD 5000 acquisition process, and the operation of the Defense Acquisition System (DAS).

1. Planning, Programming, Budgeting, and Execution System

The Planning, Programming, Budgeting, and Execution System (PPBES) is one of the three decision support processes for DoD acquisition. It is the process by which the DoD allocates resources according to its priorities and how its budgets are created.

In the Planning, Programming, Budgeting, and Execution (PPBE) process, the Secretary of Defense (SECDEF) establishes policies, strategy, and prioritized goals for the DoD, which are subsequently used to guide resource allocation decisions that balance the DoD guidance with Presidential or Congressional fiscal constraints [2].

PPBE is based on assessments of the world environment that come from either the Quadrennial Defense Review (QDR) or the National Security Strategy (NSS). A strategy is then developed that takes into account current and future threats, political stances, economic situation, technological advances, and resources. Programs, consisting of hardware, human skills, and capabilities are defined in the strategy. A budget is then created to fund the approved programs, which then is executed and reviewed to ensure that the intended strategy was achieved [30].

The PPBES is iterative; and in theory, it is supposed to be biennial[17], but it results in an annual budget cycle. The biennial budgets are supposed to support the programming guidance of the PPBE, but due to the constrained budgets and unplanned/urgent requirements, also called “fact-of-life changes,” they are not able to fully support this guidance.

The next sub-section discusses the history of PPBES, each phase of the PPBES, and the biennial PPBES cycles.

a. PPBES History

Robert McNamara, the 8th Secretary of Defense, first introduced the PPBS[18] as way to systematically analyze defense requirements and produce a long-term, program-oriented DoD budget [31].

In 1986, Congress authorized biennial budgeting in which the President submitted a two-year budget to Congress. Congress would then appropriate on a yearly basis the President’s budget.

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[17] Biennial budgets are submitted every two years.

[18] At first, it was called the Planning Programming and Budgeting System (PPBS) and later was changed to PPBES.

b. Planning Phase

The planning phase establishes the strategic priorities and capabilities required to achieve the overarching DoD strategy. It is a collaborative effort by the Office of the Secretary of Defense (OSD) and the DoD Joint Staff. This phase determines the military capabilities that are required, including the force and support level objectives to accomplish the mission. Deliverables from this phase are: Joint Strategic Review; National Military Strategy; OSD Planning; and the Strategic/Joint Planning Guidance.

The planning phase begins with clearly articulated and resource-balanced national defense policies and military strategy, also known as the Strategic Planning Guidance (SPG). The Joint Programming Guidance (JPG) evolves from the SPG, and is the link between planning and programming. The JPG provides guidance to the DoD Departments for the development of their program proposal. [2]

c. Programming

The programming phase applies resources and funds to programs that meet the capabilities required to achieve the strategic priorities. Resources are allocated to support the goals of the SPG and JPG. This phase is fiscally constrained, and thus the DoD is required to prioritize desired programs as it in translates the planning guidance into an allocation of forces, manpower, and dollars.

The programming phase begins with the development of a Program Objective Memorandum (POM), by each DoD Department[19]. The programming phase seeks to construct a set of programs, within fiscal constraints, that respond to the guidance and priorities of the JPG.

The POM provides a comprehensive description of the proposed programs, including a time-phased allocation of resources—forces, funding, and

[19] The DoD is made up of three Departments (Departments of the Army, Navy, and Air Force) and the Defense Logistics Agency. [32].

manpower—by program, projected six years into the future. DoD Departments can describe important programs that are not fully funded (or not funded at all) in the POM, including a risk assessment of what a funding shortfall would cause.

Senior DoD officials and the Joint Staff review each department's POM in order to integrate them into a coherent and overarching set of DoD programs. During these reviews they can raise issues with selected portions of any department's POM, or any funding shortfalls in the POM, and propose alternatives with adjustments to resources. The SECDEF has the final vote concerning issues not resolved at lower levels, and the resulting decisions are documented in the Program Decision Memorandum (PDM) [2].

d. Budgeting

The budgeting phase properly prices the programs, develops justifications and a budget execution plan. This occurs concurrently with the programming phase, because each branch of service submits a proposed budget estimate together with a POM.

The budget converts the POM's programmatic view into the appropriation structure used by Congressional, that will include budget justification documents. The office of the Under Secretary of Defense, Comptroller, USD(C) and the Office of Management and Budget (OMB) review each department's budget estimates. This review ensures that programs are funded in accordance with current financial policies, are properly and reasonably priced, and that the budget documentation is adequate to justify the programs when presented to the Congress.

Congressional budget analysts provide the DoD Departments with written questions in preparation for formal hearings where the analysts review and discuss the budget in detail. After the hearings, each analyst prepares a decision document (known as a Program Budget Decision, or PBD) for the programs and/or appropriations under his or her area of responsibility. The PBD proposes financial adjustments to address any issues or problems identified during the budget hearing. The PBDs are forwarded to the Deputy Secretary of Defense for decisions and these decisions are then reflected in an updated budget submission provided to the OMB.

Once each DoD Component's budget is integrated into the DoD budget, it is appended as a part of the President's Budget request to the Congress [2]. Congress must then authorize and appropriate funds for the DoD part of the President's Budget. The authorization and appropriations bills are then sent to the President for signature into law.

e. Execution

The execution phase performs the approved plan—appropriated funds are spent on authorized programs. Metrics are developed and the budget execution performance is assessed to compare actual output versus planned performance for defense programs. Resources are adjusted in order to achieve performance goals [33] [34]. If existing program performance goals of a program are not being met, the execution review may lead to recommendations to adjust resources and/or restructure programs to achieve desired performance goals. [2]

Execution review occurs simultaneously with the program and budget reviews. This is done to provide feedback concerning the effectiveness of past and current resource allocations.

f. PPBE Biennial Cycles

In 2003, the DoD adjusted the PPBE, formally known as the Planning, Programming, and Budgeting (PPB) process, to support a two-year cycle that results in biennial budgets.

Management Initiative Decision (MID) 913, dated May 22, 2003, described this process. The changes were made because the DoD's process for strategic planning, system development and acquisition, and program and budget development were not properly integrated. Although the planning and programming phases imposed fiscal discipline, they failed to integrate strategic decisions into a coherent defense program [35]. The rationale behind MID 913 was to allow the DoD to improve on

budget efforts (planning and execution). By formulating two-year budgets, the DoD could use the "off-year" (odd numbered year) to focus on budget execution and program performance [36].

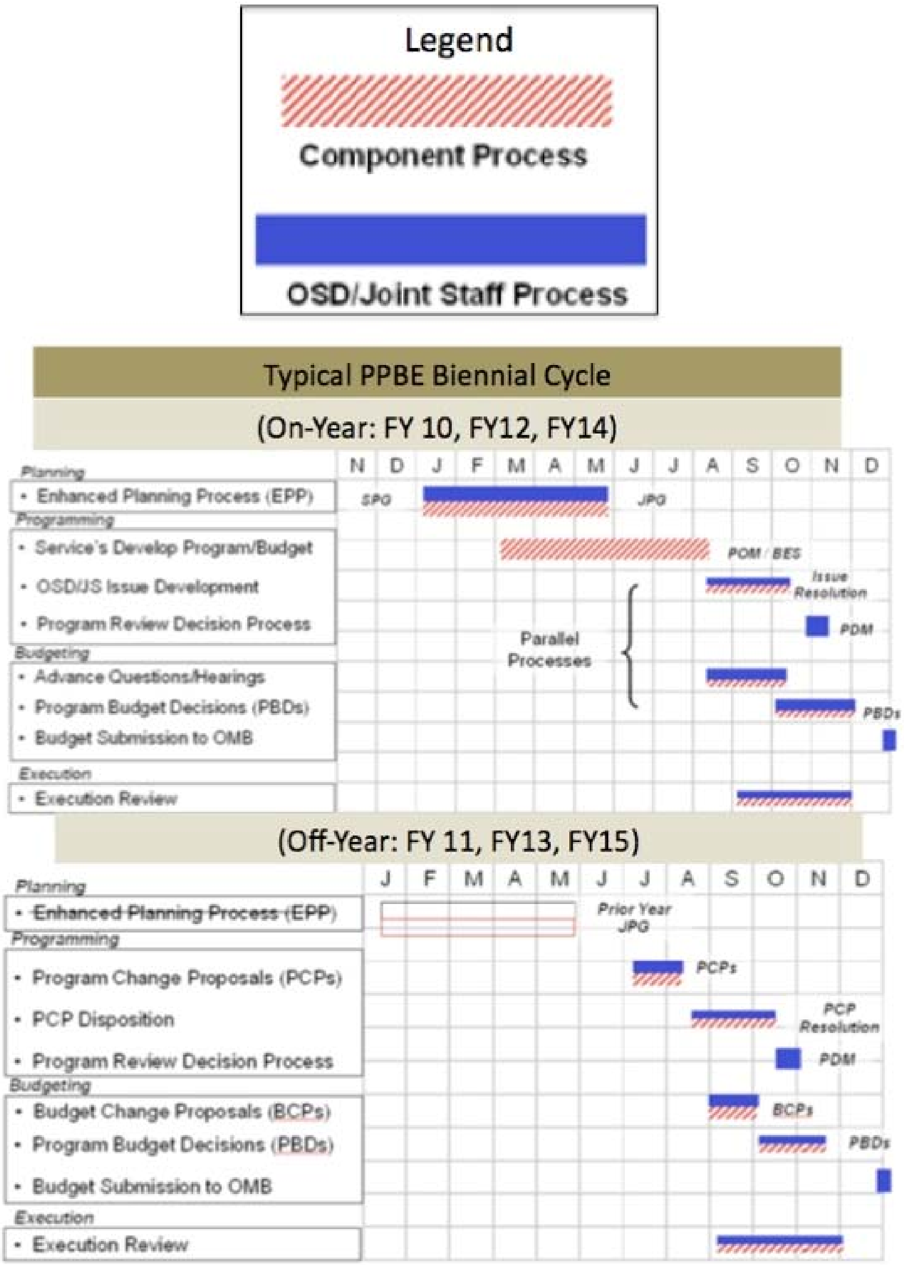

Figure 10. PPBE Biennial Cycle (On-year and Off-year) (From [34], [35])

MID 913 supported submission of a biennial DoD budget that is part of the President's Budget request to Congress for even-numbered Fiscal Years (FY) . In the biennial budget cycle, even-numbered years are called "on-years," while odd-numbered years are called "off-years." Figure 10 displays a nominal timeline for the PPBE phases in an "on-year" and "off-year."

Since Congress provides yearly appropriations to the DoD, the biennial budget is in theory submitted on an "on-year" and an amended budget justification is submitted for the "off-year," with fact-of-life changes to the budget.

In the "off-year" the DoD departments will not provide revised POMs or budget estimates, but will provide Program Change Proposals (PCPs) and/or Budget Change Proposals (BCPs) to account for fact-of-life changes. PCPs and BCPs address only single issues and identify resource reductions that will offset any program or budget cost growth.

The PPBES process takes about three years to complete. As stated earlier, all the cycles overlap and thus in June 2009 (see red vertical line in Figure 11) the DoD is executing FY09, enacting FY10, and programming FY11.

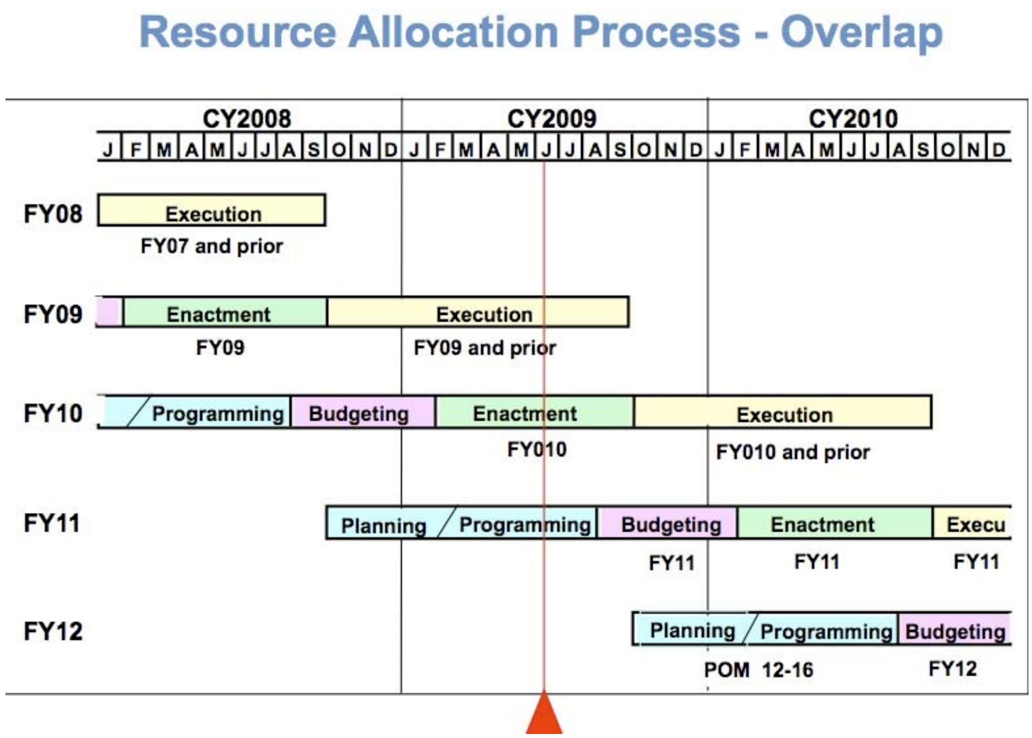

Figure 11. PPBE System Overlap (From [33])

2. Joint Capabilities Integration and Development System

The Joint Capabilities Integration and Development System (JCIDS) is the second of the three decision support processes for DoD acquisition. It is governed by the Chairman of the Joint Chiefs of Staff (CJCS) Instruction 3170.01F, and CJCS Manual 3170.01C. The *Defense Acquisition Guide* (DAG) calls JCIDS "a joint-concepts-centric capabilities identification process that allows joint forces to meet future military challenges."

The primary objective of the JCIDS process is to ensure that the end-user receives the capabilities required to successfully execute the assigned missions. JCIDS is a series of top-down analyses, derived from strategic-level guidance, that identifies capability gaps[20] and a potential solution by assessing existing and proposed capabilities in contrast to their contribution to future joint concepts, in the context of integrated architectures of

[20] Capability gaps are analyses that take warfighter requirements and determine if an existing system can meet that requirement, or if a new solution is required [37].

multiple interoperable systems. The JCIDS process supports DoD acquisition by providing validated capabilities and associated performance criteria to be used as a basis for acquiring the right weapon systems and by providing the PPBES with prioritization and affordability advice [37]. The capability gaps are addressed by a combination of materiel and/or non-materiel solutions[21]. The recommended materiel solutions, once approved, lead to acquisition programs.

JCIDS encourages collaboration between end-users (the warfighters) and system developers (the providers) early in the process. This improves the ability of many DoD organizations to influence what the proposed solutions will be to the capability gaps.

a. JCIDS Origins and the Joint Requirements Oversight Council

The JCIDS process was created to support the Joint Requirements Oversight Council's (JROC) strategic requirements to validate and prioritize joint warfighting requirements.

The JROC's mission is to assist the CJCS in identifying and assessing the priority of joint military capabilities (including existing systems and equipment) to meet the national military and defense strategies and in considering alternatives to any acquisition program by evaluating the cost, schedule, and performance criteria. In addition, it ensures that the assignment of capability priorities conforms to and reflects projected DoD resource levels, as stated in the JPG. [38]

The JROC reviews programs designated as JROC interest and supports the acquisition review process in accordance with U.S. Code [38]. The JROC reviews and validates all JCIDS documents for Acquisition Category (ACAT) I and IA programs (see Table 1) and other programs that are designated as high-interest. For ACAT ID and IAM programs, the JROC reviews and makes recommendations to the Defense Acquisition Board (DAB) or Information Technology Acquisition Board (ITAB).

[21] Non-materiel solutions would be changes to doctrine, organization, training, materiel, leadership and education, personnel, and facilities—also known as DOTMLPLF.

Acquisition Category (ACAT)	Reason for ACAT Designation
ACAT 1	* Major Defense Acquisition Program (MDAP) with dollar value: more than $365 million in fiscal year (FY) 2000 constant dollars * For procurement, of more than $2.190 billion in FY 2000 constant dollars * Milestone Decision Authority (MDA) designation as special interest
ACAT 1A	* Major Automated Information System (MAIS): A DoD acquisition program for an Automated Information System (AIS) (either as a product or a service) that is either: a) Designated by the MDA as a MAIS; or b) Estimated to exceed: $32 million in FY 2000 constant dollars for all expenditures, incurred in any single fiscal year; or * $126 million in FY 2000 constant dollars for all expenditures, directly related to the AIS definition, design, development, and deployment, and incurred from the beginning of the Materiel Solution Analysis Phase through deployment at all sites; * $378 million in FY 2000 constant dollars for all expenditures, directly related to the AIS definition, design, development, deployment, operations and maintenance, and incurred from the beginning of the Materiel Solution Analysis Phase through sustainment for the estimated useful life of the system. * MDA designation as special interest
ACAT II	* Does not meet criteria for ACAT I * Major system a) Dollar value: estimated to require an eventual total expenditure for RDT&E of more than $140 million in FY 2000 constant dollars b) For procurement of more than $660 million in FY 2000 constant dollars
ACAT III	* Does not meet criteria for ACAT II or above * AIS that is not a MAIS

Table 1. Summary of Acquisition Categories (From [39])

The JROC is chaired by the Vice CJCS, by delegation from the CJCS [40] who also serves as the co-chair of the DAB. The other JROC members are the Vice Chiefs of each military service [41].

b. JCIDS Process

The JCIDS process evaluates existing and proposed capabilities in light of their contribution to future joint concepts. JCIDS is supported by robust analytic processes and identifies capability gaps and potential solutions. While JCIDS considers the full range of Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) solutions, the focus remains on the pursuit of "materiel" solutions [2].

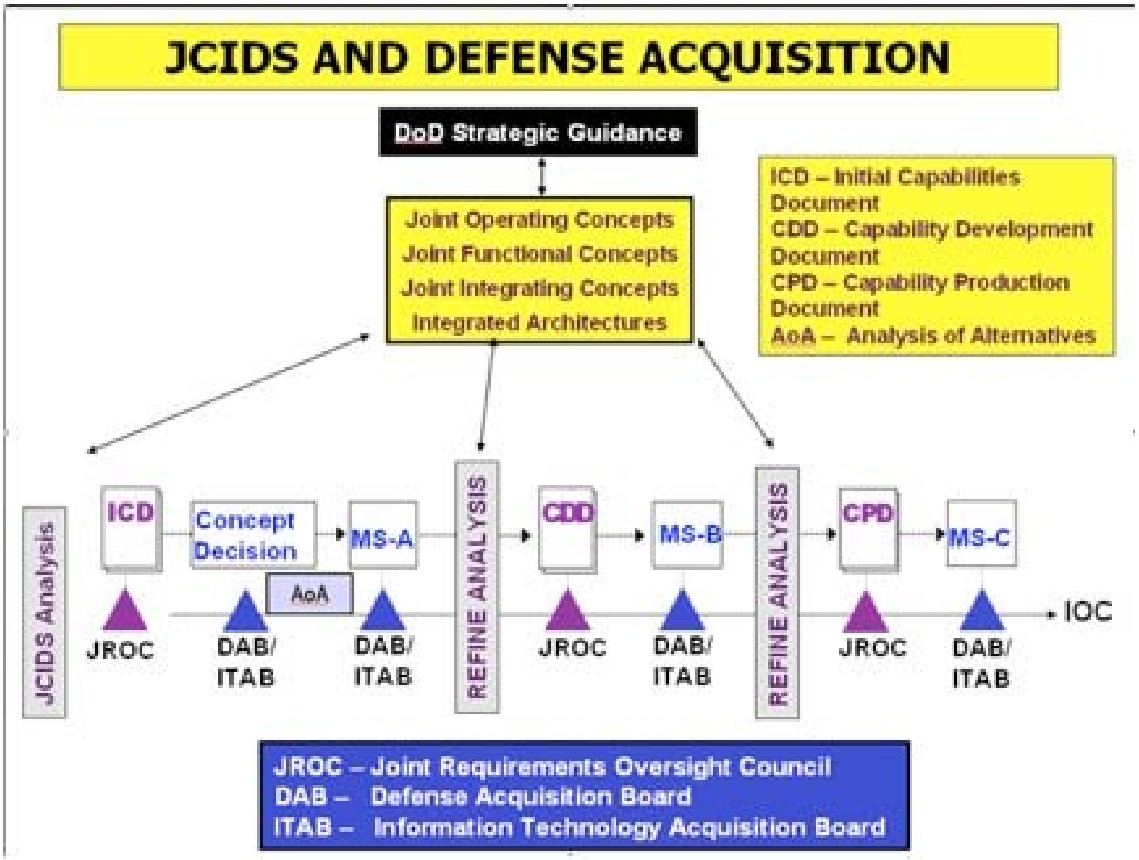

Figure 12. JCIDS interaction with Defense Acquisition (From [2])

The JCIDS process is initiated through the execution of a Capabilities-Based Assessment (CBA). The CBA is based on high-level military doctrine, such as the Joint Operating Concept (JOC) and the Joint Integrating Concept (JIC). The CBA carefully evaluates the required capabilities, compares them to the shortfalls in weapon systems and the inherent operational risk, and develops a potential solution for the capability shortfall.

The results of the CBA are documented in a Joint Capabilities Document (JCD), or Initial Capabilities Document (ICD), that validate the need for a certain capability, and describe a potentially affordable and technically feasible solution [37]. As the CBA is refined in an iterative process, the ICD will be incorporated into the Capabilities Development Document (CDD), which, in turn, will be incorporated into the Capability Production Document (CPD). Figure 12 shows how the JCIDS process interacts with different phases of DoD acquisition.

3. The Defense Acquisition System—Little “a” Acquisition Process

The third part of the support process for DoD acquisition is the Defense Acquisition System (DAS). DoD Instruction 5000.02 and DoD Directive 5000.01 govern the DAS, and it is commonly known as the little “a” acquisition process shown in Figure 9. These instructions lay the framework of how the DoD will acquire systems that are effective, affordable, and delivered in a timely manner. The DAS is the management process by which the DoD acquires weapon systems and automated information systems.

The DAS framework provides an event-based process, where acquisition programs proceed through a series of milestones associated with significant program phases. It also identifies specific statutory and regulatory reports and other information requirements for each milestone and decision point. A key principle of defense acquisition is the use of ACAT (see Table 1), where programs with increasing dollar value and management interest are subject to more stringent oversight.

Major Defense Acquisition Program (MDAP) and Major Automated Information Systems (MAIS) are the most expensive acquisition systems and information systems programs, as shown in Table 1. Most MDAP and MAIS are subject to review by senior DoD officials, these are normally ACAT 1 or ACAT 1A. ACAT 1D programs are subject to review by the Under Secretary of Defense for Acquisition, Technology, and Logistics, USD(AT&L). ACAT 1AM programs are MAISs that are reviewed by the Assistant Secretary of Defense for Networks and Information Integration/ DoD Chief Information Officer (ASN(NII)/DoD CIO).

These individuals are the Milestone Decision Authority (MDA) for their respective programs. The MDA reviews programs and decides if programs will continue to move past milestone points [39].

4. Operation of the Defense Acquisition System

Figure 13 depicts the Defense Acquisition System (DAS). The DAS has five phases: Materiel Solution Analysis (MSA); Technology Development (TD); Engineering and Manufacturing Development (EMD); Product and Deployment (PD); and Operations and Support (OS). Entrance into the Defense Acquisition Management Systems (DAMS)

requires a Material Development Decision (MDD). Each phase has specific entrance and exit criteria, which are specified at the MDD or Milestone A, B, or C reviews or once production has completed.

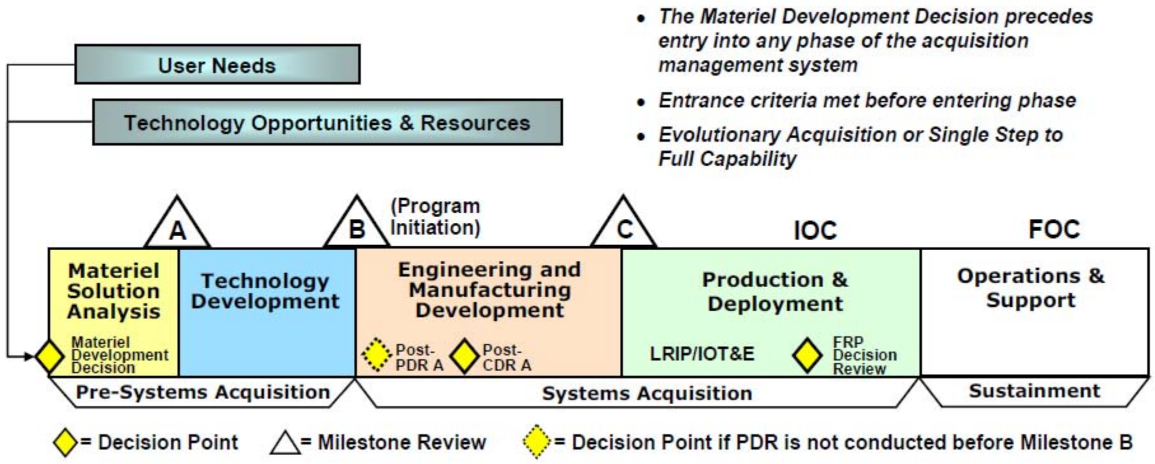

Figure 13. The Department of Defense Acquisition System (From [39])

a. Materiel Development Decision

A MDD is required regardless of what phase of the acquisition process the program intends to enter. The MDD is the formal entry point into the acquisition process and is a mandatory step that ensures entry phase decisions are based on approved requirements and on a rigorous assessment of alternatives. The JCIDS process overlaps into the DAS at the MDD, where a materiel decision is made.

The DoD plans a MDD review, with the MDA, when a need for a materiel solution is shown. The MDA examines the ICD and then can approve the guidance from the Analysis Of Alternatives (AoA). The AoA is a study intended to aid decision making by illuminating the risk, uncertainty, and the relative advantages and disadvantages of alternatives being considered, to satisfy a mission need [42].

Once the MDD is complete, the MDA determines acquisition phase of entry (see Figure 14) and documents its decision in an Acquisition Decision Memorandum (ADM) [39],[43].

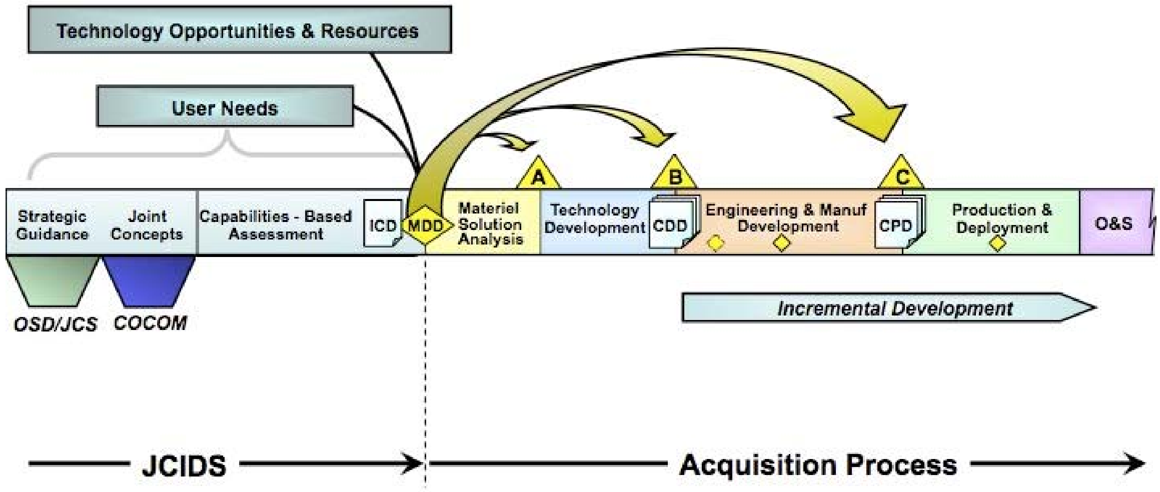

Figure 14. Materiel Development Decision and Acquisition Entry Phase (From [43])

b. Materiel Solution Analysis Phase

The purpose of this DAS phase is to assess potential materiel solutions and to satisfy the entrance criteria for the Technology Development Phase.

The MSA phase begins with an approved ICD that has a preliminary concept of operations, a description of the needed capabilities, and the program risk. Although an ADM was signed for the MDD, this does not mean that a program has been initiated[22]. In the MSA phase, the DoD component begins to assess preliminary materiel solutions, identify key technologies, and estimate life-cycle cost. This phase culminates once the specific exit criteria of the phase have been attained and a materiel solution is approved at the Milestone A review [39],[43]. The purpose of the MSA phase is to develop materiel solution options for the identified capability need.

c. Technology Development Phase

The focus of the TD phase is to reduce technology risk, determine and mature the appropriate set of technologies to be integrated into a full system, and to demonstrate critical technology elements in a prototype.

[22] Program initiation normally occurs after the Milestone B review.

TD is a process of continuous technology discovery and development that requires close collaboration between the Science and Technology (S&T) community, the end-user, and the system developer. It is an iterative process designed to assess the viability of technologies while simultaneously refining end-user requirements. If technology is found not to be mature, the DoD component can use alternative technology that is mature and that can meet the end-user's needs or engage the user in a dialogue on appropriately modifying the requirements.

A system enters this phase after fulfilling an AoA, with an approved materiel solution (done at the Milestone A review), and after being fully funded for the technology development phase. This phase requires competitive prototyping of the system or key-system elements as well as a Preliminary Design Review (PDR) that must be conducted for the candidate designs. A PDR report is provided to the MDA with recommended requirements trade-offs [43].

The Technology Development Strategy (TDS) is a document that is drafted during the MSA phase, and finalized during the TD phase. The TDS documents the following: preliminary acquisition strategy (costs schedule, and performance goals); specific cost and schedule; and performance goals for the technology development phase.

This phase is exited when an affordable program or increment of military capability has been identified. This means that the technology and manufacturing processes have been assessed, demonstrated in the applicable environment, manufacturing risks have been identified, and the system can be developed within a short period of time [43].

A Capabilities Development Document (CDD) will be prepared to support initiation of the acquisition program. The CDD builds on the ICD and provides the detailed operation performance parameters of the system. Once a program passes the Milestone B, the TD phase is completed and indicates program initiation.

(1) Preliminary Design Review. The Preliminary Design Review (PDR) can occur before or after Milestone B review, but that depends on how the TDS or ICD are written. A PDR occurs before Milestone B when this satisfies TD phase objectives,

associated prototyping activity and the approved TDS, and if the Program Manager (PM[23]) desires. The PDR should be conducted at the system level and include end-user representatives and certification stakeholders.

PDR planning is conducted in order to establish the program baseline (hardware, software, and human/support systems), underlying architectures and to define a high-confidence design. All system elements (hardware and software) require an adequate level of maturity for a successful PDR.

If PDR is not conducted prior to program initiation, Milestone B, it should be done soon after entrance in the EMD phase (see Figure 15).

Following PDR, the PM submits a PDR report and the MDA conducts a formal Post-PDR Assessment. The PDR report reflects any requirements trades based upon the PM's assessment of cost, schedule, and performance risk [43]. The results of the MDA's Post-PDR Assessment are documented in an ADM. A successful PDR will inform requirements trades; improve cost estimation; and identify remaining design, integration, and manufacturing risks.

The Milestone B decision allows the MDA to determine the Low-Rate Initial Production (LRIP) quantities for MDAPs and major systems [39],[43].

[23] The PM is the DoD designee that supervises the development or acquisition of a system.

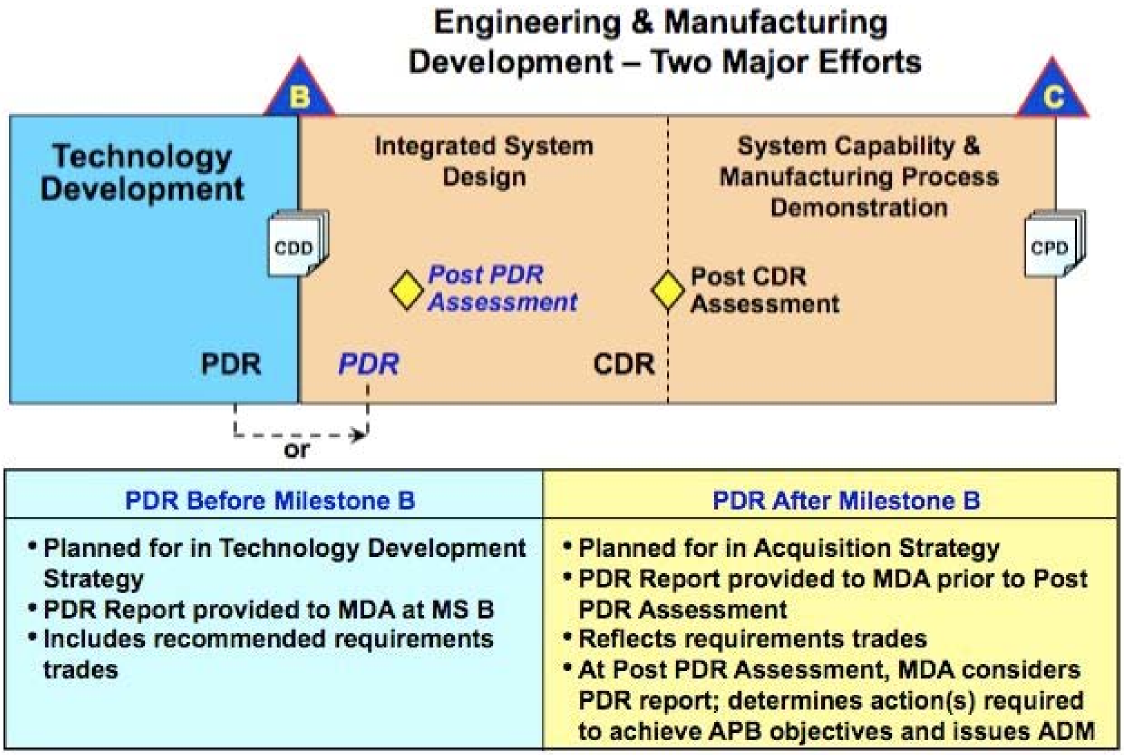

Figure 15. Preliminary Design Review (From 43])

d. *Engineering and Manufacturing Development Phase*

The purpose of the Engineering and Manufacturing Development (EMD) phase is to develop a system or an increment of capability; complete full system integration; develop an affordable and executable manufacturing process; ensure operational supportability (minimizing the logistics footprint); implement Human Systems Integration (HSI); design for producibility; ensure affordability; and demonstrate system integration, interoperability, safety, and utility [39].

The EMD phase is guided by the CDD, acquisition strategy, Systems Engineering Plan (SEP), and Test and Evaluation Master Plan (TEMP). The emphasis of this phase is SE and technical reviews. The PM may provide a PDR report, if not done during the TD phase (see Figure 15) and must provide a Critical Design Review (CDR) report to the MDA.

Figure 15 shows that the EMD phase has two major efforts: Integrated System Design; and System Capability and Manufacturing Process Demonstration. The post-CDR assessment, conducted at the end of the Integrated System Design effort, allows the MDA to determine if the results of the CDR warrant continuing the phase to Milestone C.

The Integrated System Design effort is intended to define system and SoS functionality and interfaces, complete hardware and software detailed design, and reduce system-level risk. The program can enter the System Capability and Manufacturing Process Demonstration effort part of this phase upon completion of the Post-CDR Assessment and establishment of an initial product baseline.

The System Capability and Manufacturing Process Demonstration effort is intended to demonstrate the ability of the system to operate in a useful way consistent with performance requirements and that the manufacturing processes can support system production.

This effort will end when the system meets approved requirements and is demonstrated in its intended environment. In addition, manufacturing processes have been effectively demonstrated, industrial capabilities are reasonably available, and the system meets Milestone C entrance requirements. The completion of this phase is dependent on a decision by the MDA to commit to the program at Milestone C or a decision to terminate the project [39],[43].

e. Production and Deployment Phase

The purpose of the Production and Deployment (PD) phase is to achieve an operational capability that satisfies mission needs. Operational test and evaluation will determine the effectiveness and suitability of the system. The ADM documents the commitment to production at Milestone C.

A positive Milestone C decision authorizes entry into LRIP (for MDAPs and major systems), into production or procurement (for non-major systems that do not require LRIP) or into limited deployment in support of operational testing for MAIS programs or software-intensive systems with no production components.

Full Rate Production (FRP) decision requires demonstrated control of the manufacturing process and acceptable reliability in process control data, and the demonstrated control and capability of other critical processes. The beyond LRIP decision is based upon the MDA FRP decision review, and documented in an ADM [39].

f. Operations and Support Phase

The purpose of the Operations and Support (OS) Phase is to execute a support program that meets materiel readiness and operational support performance requirements, and sustains the system in the most cost-effective manner over its total life-cycle. OS has two major efforts, Life-Cycle Sustainment and Disposal [39].

g. Evolutionary Acquisition and Recent DoD Acquisition Changes

Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the end-user. An evolutionary approach delivers capability in increments, recognizing up front the need for future capability improvements. It requires a careful balance between available capability and resources, and the desire to put that capability in the hands of the user quickly [43].

Each capability increment is designed to give additional capabilities to the end-user. When evolutionary strategy is used, the initial delivered capability represents only partial fulfillment of the overall capability described in the ICD, and successive technology development efforts continue until all capabilities have been achieved. In an evolutionary acquisition, the identification and development of the technologies necessary for follow-on increments to continue, in parallel with the acquisition of preceding increments, allows the mature technologies to more rapidly proceed into the EMD Phase. Each increment of an evolutionary acquisition program will include a Milestone A and will have an MDA-approved TDS (see Figure 16) [39].

With evolutionary acquisition, increments of capabilities are deployed to the end-user in a time-phased basis. Figure 16 shows the development flow through the DAS; it shows how there can be parallel capability development cycles that continually improve the capabilities of the systems being developed in the previous development increment. Specifically, as an acquisition transitions from MSA phase, through MS "A" review, through the TD phase and MS "B" review, a decision is made by the Defense Acquisition Board (DAB[24]) to begin the next increment of capability for the systems.

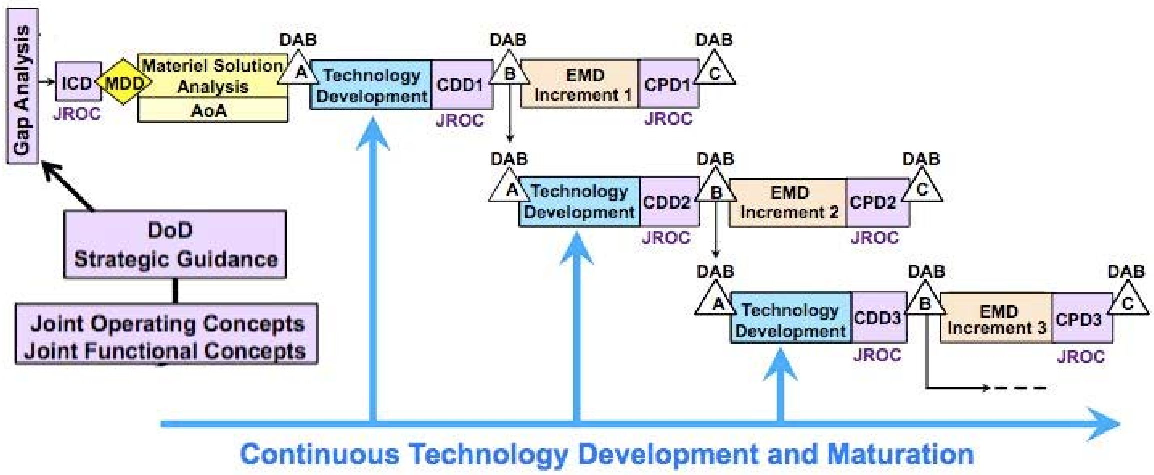

Figure 16. Evolutionary Acquisition (From [43])

Having discussed the DoD acquisition system, the next section of this chapter will discuss how SE has effected the way systems are acquired by the DoD.

C. SYSTEMS ENGINEERING IMPACT ON DEPARTMENT OF DEFENSE ACQUISITION

DoD Instruction 5000.02 specifies that SE be used in the acquisition life-cycle. It claims that "rigorous SE discipline is necessary to ensure that [DoD] meets the challenges of developing and maintaining needed warfighting capability." Furthermore, it requires that SE be "embedded in program planning" [39].

[24] The DAB is the senior advisory board for defense acquisitions in the DoD. The board's make up is similar to the make up of the JROC and includes the Vice CJCS, the service Secretaries, and a number of Undersecretaries of Defense. The DAB plays an important role in the DAS. Members of this board are responsible for approving the Major Defense Acquisition Programs (MDAP) [44].

SE provides a way to integrate the system development processes that will define future system performance, cost, schedule, and risk. As systems become larger and more complex, the design, development, and production of a system, or SoS, require the integration of numerous activities and processes. The DoD has recognized the importance of using the SE approach in achieving an integrated and balanced system solution. [2]

There are many beneficial impacts that arise from the use of SE for DoD acquisition. They begin with the careful elicitation of end-user requirements that focus on designing the right system. They continue through the diligent integrated product design that ensures that the end product will be able to be assembled and that the sub-systems will correctly interface with each other. Most importantly, SE allows the PM to effectively use the design tradespace to mitigate risks (cost, schedule, performance) in order to deliver a product that meets the end-user's need, is delivered in a timely manner, and is affordable. SE and the SE process will be further discussed in Chapter IV.

D. CONCLUSION

This chapter has discussed how the DoD acquisition system operates and will be the foundation (DoD acquisition) for discussing the need for the NCAP. The three decision support processes for DoD acquisition were briefly presented and explained. There are many nuanced inter-relations between the three systems where a small change in one can have large impact in one of the others. If the changes are large enough, it can have devastating effects for DoD acquisition (e.g., Littoral Combat Ship (LCS)). The interaction between these three processes is delicate and if not properly handled can create inefficiencies in the acquisition of DoD systems.

These three processes provide an integrated approach to strategic planning, identification of needs for military capabilities, systems acquisition, and program and budget development that ultimately are responsible for providing the warfighter with the right capability, at the right time, and in an affordable way.

Chapter IV will discuss the SE approach to acquisition by explaining the SE processes.

IV. SYSTEMS ENGINEERING APPROACH TO ACQUISITION

A. OVERVIEW

The role of SE is to elicit the needs of the customer[25]; identify appropriate system requirements; develop a system architecture from which to design and build the applicable Configuration Items (CI); and integrate the CI to produce a system, or SoS, which meets the needs of the customer.

According to the *Systems Engineering Guide for Systems of Systems*:

> An SoS is defined as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. Both individual systems and SoS conform to the accepted definition of a system in that each consists of parts, relationships, and a whole that is greater than the sum of the parts; however, although an SoS is a system, not all systems are SoS. [45]

SE is involved in each phase in the system or SoS's life-cycle. The SE processes are applied early in the materiel solution development and then continuously throughout the total system life-cycle [2]. The best system solutions are achieved by applying established SE processes continuously to the planning, development, and implementation of a system or SoS acquisition.

SE is typically implemented through multi-disciplined teams of subject matter experts, who translate user-defined capabilities into operational system specifications consistent with cost, schedule, and performance constraints. SE uses a total life-cycle view that encompasses the "cradle to grave" planning. Since cost to implement system changes increases as a product moves further along its life-cycle, the SE approach encourages the leverage of early trade-offs in system design. Early identification and timely mitigation of system design, schedule, and integration issues reduce overall system acquisition cost. The Systems Engineering Plan (SEP), which is an overarching development strategy for the system, should be established early in the system development, and be updated as the program matures [2].

[25] In the DoD the customer, end-user, or warfighter is considered the generator of requirements because they are the ones that need it.

This chapter will present a small sample of different SE processes, define a generic SE process (events, phases, and stakeholders), and then describe how the SE process is mapped/applied to the DoD acquisition process.

B SYSTEMS ENGINEERING PROCESSES

There are many different SE approaches that can be used in the DoD acquisition process. Chapter 4 of the *Defense Acquisition Guide* (*DAG*) refers to several process standards and capability models that describe best practices and processes for conducting systems engineering [46]. Some of the process models presented in the *DAG* are:

- *ISO/IEC 15288*, Systems and Software Engineering-System Life-Cycle Processes
- *ISO/IEC 12207*, Systems and Software Engineering-Software Life-Cycle Processes
- ANSI/EIA 632, Processes for Engineering a System.

There are many different SE process standards, but they all share a common element—the detailed breakdown of system requirements in order to design and create a system that meets the customer's requirements. The following sub-sections will present three well know SE process models, the SE "Vee," the Waterfall, and the Spiral.

1. Systems Engineering "Vee"

The SE Vee, Figure 17, is a graphical representation of the system development cycle. The main steps to be taken for product development are summarized. The left side of the Vee decomposes the requirements and creates system specifications—called the project definition. The bottom and right side of the Vee show the build, testing, integration, and verification of system components—called the project build, integration and test.

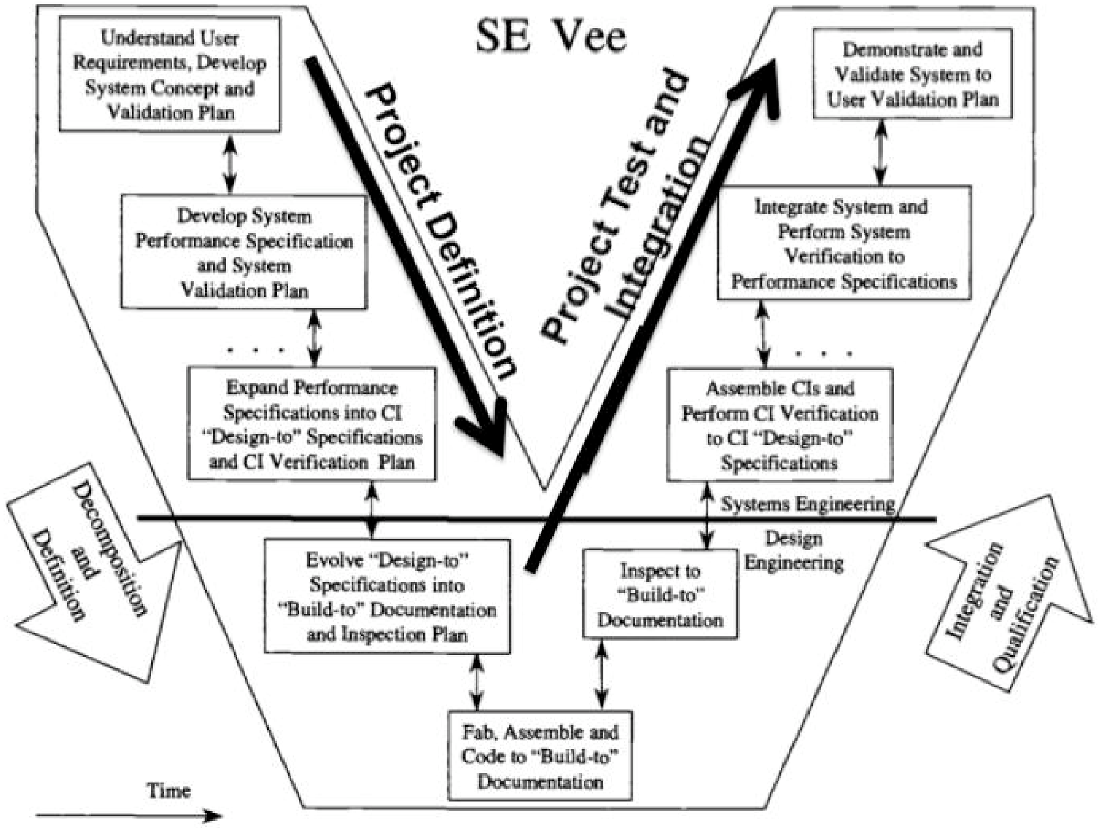

Figure 17. Systems Engineering "Vee" (From [47])

2. Waterfall Model

Figure 18 shows the waterfall model and is more applicable to software engineering than to other forms of engineering. This SE model is a sequential, mostly software, development process in which iteration is allowed between adjacent phases. The major problem with the waterfall model is that iteration between non-adjacent phases occurs too frequently (i.e., between software requirements and detailed design) [47].

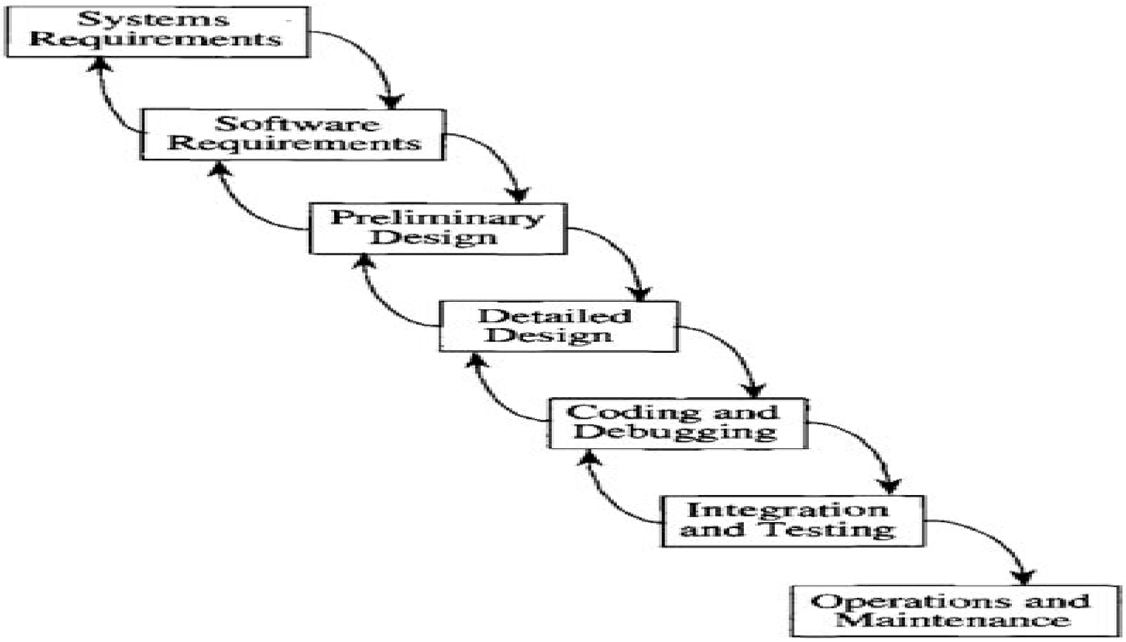

Figure 18. Waterfall Model of Software Engineering (From [47])

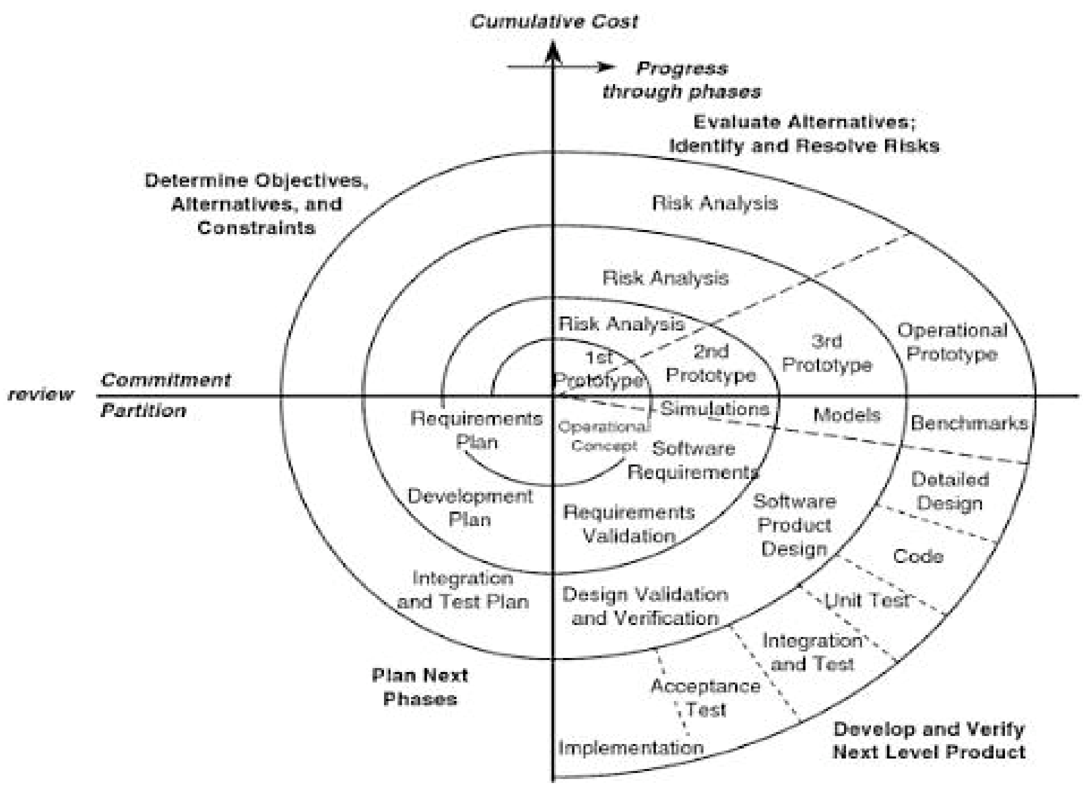

Figure 19. Spiral Model (From [47])

3. Spiral Model

Figure 19 shows the spiral model. It is primarily a software development process model where elements of design and prototyping are combined. This model combines features of the prototyping and waterfall models. Characteristic of this model is the sequential evolution of development cycle phases, where iteration is only allowed between adjacent phases. This process model addressed the need to reduce production time. It shortened the time from user requirement definition to the delivery of a useful product [47].

4. *Defense Acquisition Guide's* Systems Engineering Process

Figure 20 shows the *DAG*'s SE process (rows of the figure), and it shows how the different phases of the SE approach (columns of the figure), used by the *DAG*, map onto the different phases of the DoD acquisition process. Interestingly, some of the technical process phases occur almost concurrently[26], where the majority of the level of effort, or cost, is done during the same phase of the acquisition process.

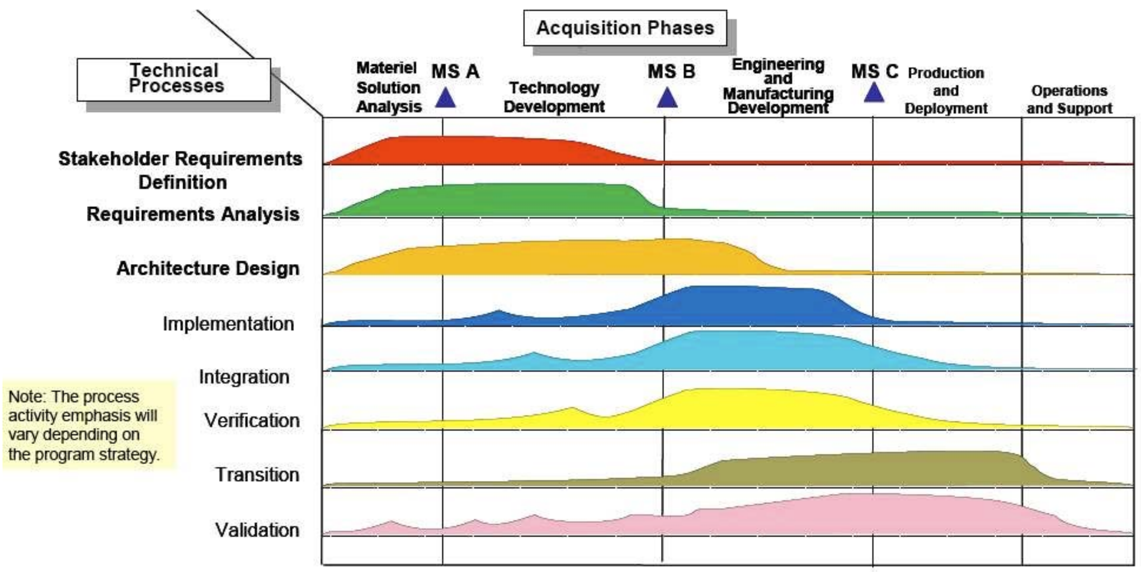

Figure 20. Systems Engineering Technical Processes and the Acquisition Life-Cycle (From [46])

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[26] For example, Figure 20 shows that Stakeholder Requirements Definition, Requirements Analysis, and Architecture Design processes are taking place during the MSA and TD phases of the DoD acquisition process.

The SE process described in the *DAG* is similar to the SE "Vee" described in Figure 17. The *DAG* SE process shows a direct mapping of *DAG* technical processes to the DoD acquisition process timeline (discussed in Chapter III).

C. MAPPING THE GENERIC SYSTEMS ENGINEERING APPROACH TO THE DEPARTMENT OF DEFENSE ACQUISITION PROCESS

In order to map the DoD acquisition processes to the various SE models, a generic SE approach is used (discussed in the Appendix). Figure 21 shows how the generic SE approach and types of people that typically work in each phase (as described in the Appendix) would be mapped to the DoD acquisition system, discussed in Chapter III, and as seen in Figure 13. This mapping is done to show that the many SE approaches can be utilized in a parallel way that complements the DoD Acquisition System framework.

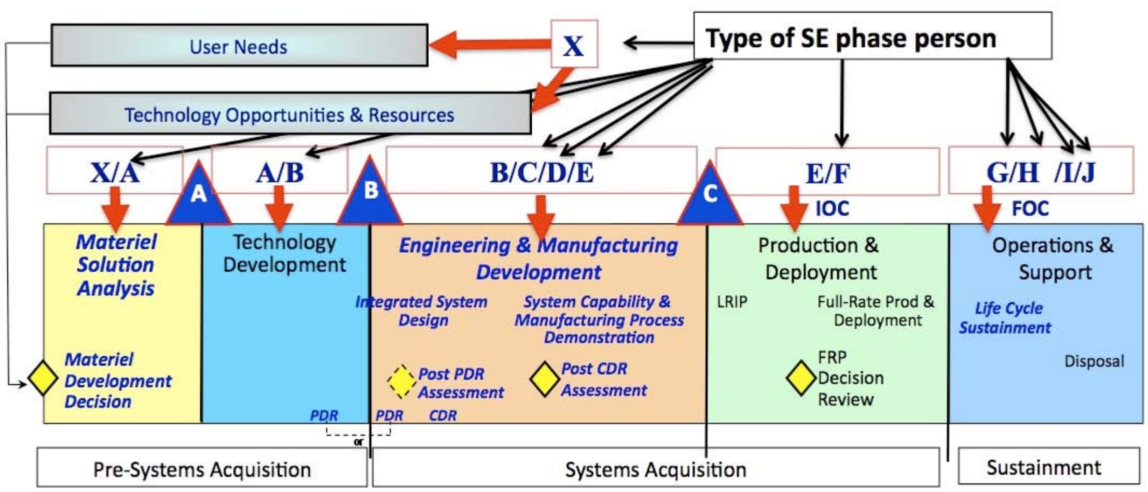

Figure 21. Systems Engineering Process Mapping to DoD Acquisition System (From [48])

1. Materiel Solution Analysis Phase

In the early phases of system acquisition, the customer, "X"[27] type person interacts with the sales, marketing, and acquisition personnel, the "A"[28] people, to begin the system design. The early system design takes into consideration the technology opportunities, schedule and funding constraints, and system performance parameters in order to correctly express the Key Performance Parameters (KPP) of the system.

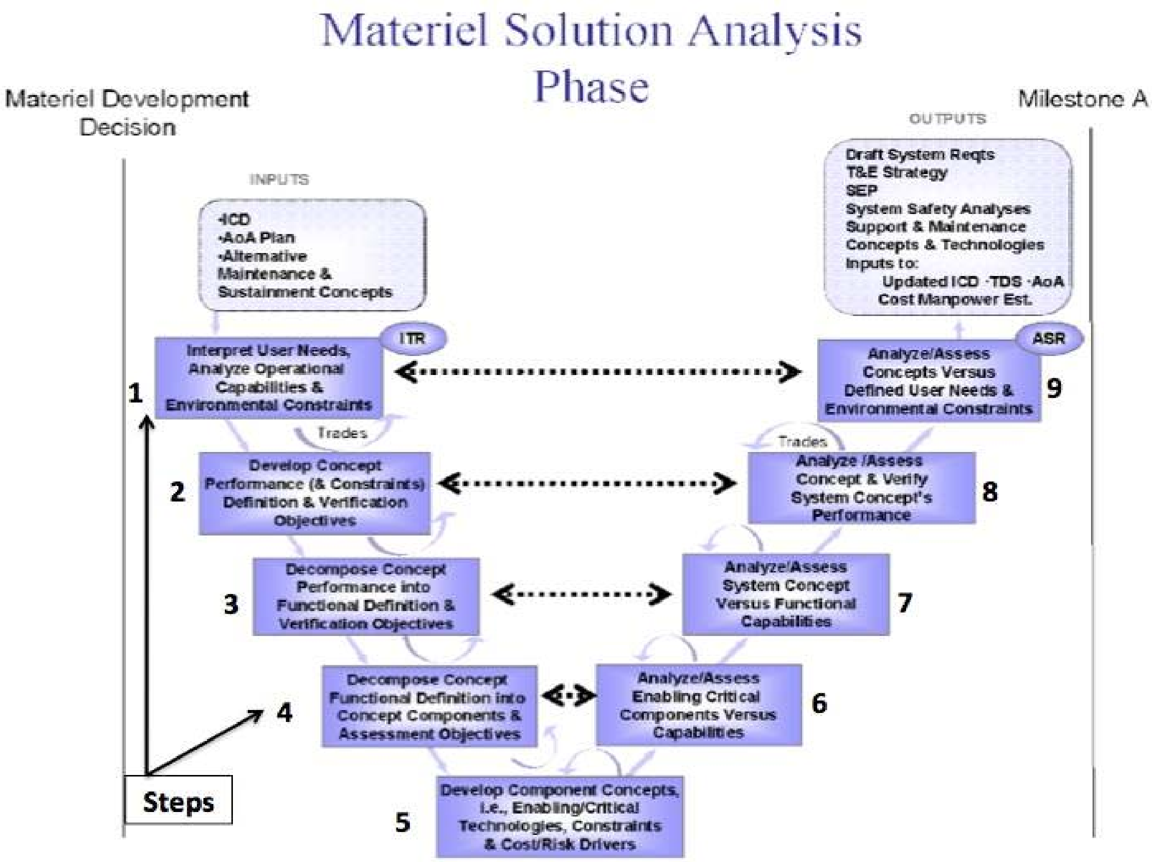

Figure 22. System Engineering Steps During Materiel Solution Analysis Phase (From [46])

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[27] From the Appendix, "X" people are the "big picture" thinkers, visionaries, and dreamers. "X" people take the end-user needs, analyze them, and are capable of correctly describing the capability gap—the need—that requires a materiel solution. Since they understand the "big picture," they do not concern themselves with the intricate details of the systems they require.

[28] From the Appendix, "A" people interact constantly with the customer, "X" types, thus "A" people usually have marketing, business, and detail design experience . "A" people need to be able to effectively communicate with the customer to correctly elicit the system requirements. "A" people need to also interact with "B" people, to make sure what they plan is technically feasible, and therefore "A" people with technical backgrounds (typically were a "B" person previously) are more successful.

Figure 22 shows the SE process steps (using the SE "Vee") conducted during the MSA phase. It is interesting to note that each step has a capabilities "trades" process that is iterative, where the customer and system developer can modify the design in order to make the system better meet the customer's requirements.

There are many steps taken during the MSA phase, on the left and downward side of the SE "Vee." The project team interprets user's needs (step 1), develops the concept performance (steps 2 & 3), and decomposes the concept into components and objectives (steps 4 & 5). On the right and upward side of the SE "Vee," the system design is integrated and analysis is done on enabling components, overall system functionality, overall system performance and constraints, and fulfillment of defined user needs (steps 6 thru 9)[46].

a. Materiel Solution Analysis Technical Reviews

Technical reviews performed during the MSA phase include the Initial Technical Review (ITR), which is done at the beginning of the MSA phase, and the Alternative System Review (ASR), which is done at the end of the MSA phase. The ITR attempts to ensure that a program's technical baseline can support a valid cost estimate (evaluating cost risk), and assesses the capability needs and materiel solution approach of a proposed program.

The ASR is a technical review that tries to ensure that the elicited set of requirements agrees with the customers' needs and expectations and that the system under review can proceed into the Technology Development phase. The ASR is important because it attempts to minimize the number of requirement that will need to be changed in later phases. The ASR should be completed prior to, and provide information for Milestone A [46].

b. Materiel Solution Analysis Phase Outputs

Some of the outputs from the MSA phase include: Preliminary System Specification; Test and Evaluation Strategy; SEP; and Inputs to draft Capability Development Document (CDD) and AoA.

2. Technology Development Phase

Figure 21 shows that in this phase "A" and "B"[29] people interact in an attempt to mature technologies into an end-system configuration. This phase determines the appropriate set of technologies to be used, conducts competitive prototyping, refines requirements, and develops baselines for system configuration.

According to the *DAG*, in this phase:

> [SE] processes help mature, prototype, and demonstrate the selected system elements and complete the preliminary design of the full system for low-risk entry to the [EMD] phase.

Figure 23 shows the SE related steps that are conducted in the TD phase. The first step (step 1) attempts to interpret the user's need by using the outputs from the previous phase (some being the ICD, CDD draft, material solution, T&E strategy, SEP, and TDS). Additional analysis may be required to ascertain all of the constraints (such as operational environment, resource-industrial base, operation and support budgets, system fielding date, technology base, and statutory constraints). Key to the TD effort is ensuring that the required technologies are properly matured.

[29] From the Appendix, "B" phase people are engineers with technical experience that push the technology boundaries with a "can do" attitude that is at times overly optimistic. "B" people interface with "A" and "C"; therefore they need to technically commit to "A" and make sure the plan is feasible for "C" people and encourage "C" people that this system is doable (show them the system vision).

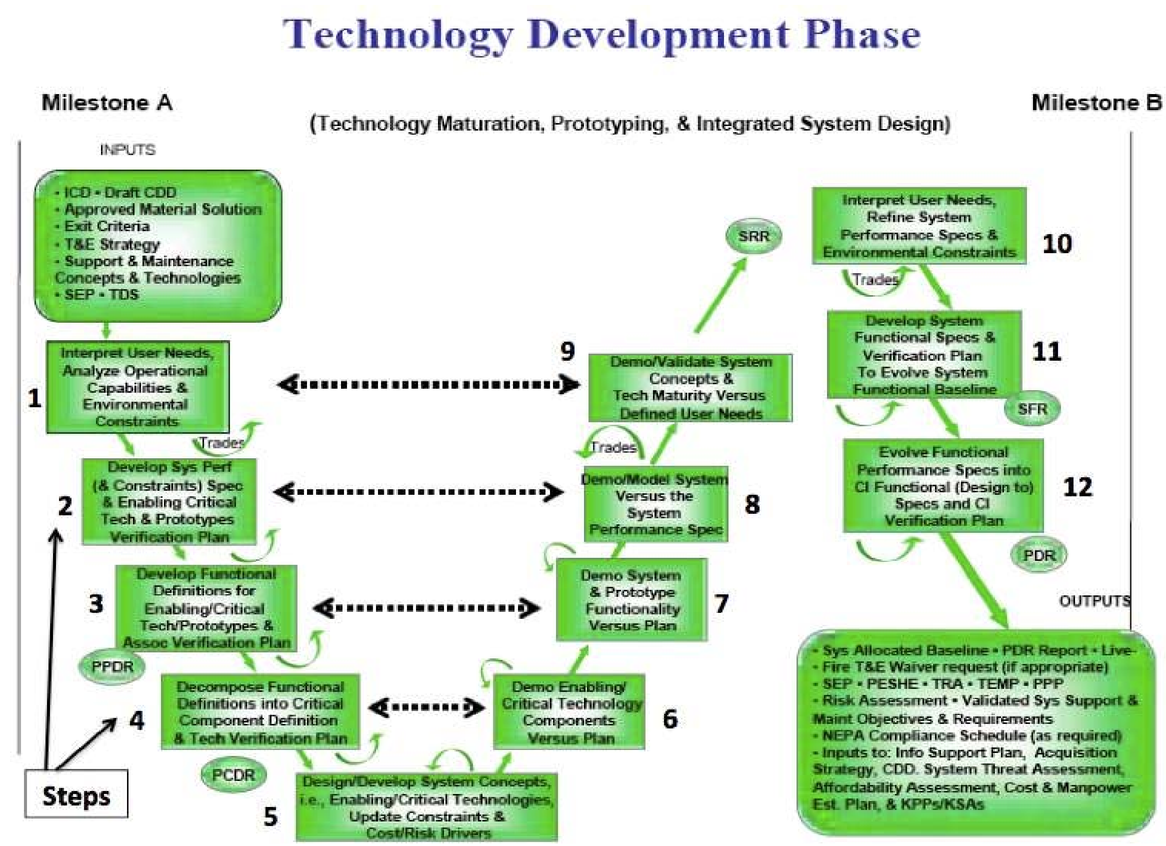

Figure 23. System Engineering Related Steps During Technology Development Phase (From [46])

The SE process then steps through the development of system performance specifications and functional definitions (step 2). There is analysis and decomposition from the capability level to the system level and to the functional level.

The next two steps (steps 3 and 4) decompose functional requirements into critical components by evaluating available technologies so that they can provide the required functionality. Then the system functions are allocated into critical components of the systems, that will provide the required functionality. The requirements trade space will be used to maximize fidelity to the system specifications while following program constraints and program risk.

At the bottom of the "Vee" (step 5), system concepts are developed and designed, and prototypes are demonstrated that show the viability of the overall system and where critical technology maturation should occur.

Moving up the "Vee" (steps 6–9), the steps demonstrate: desired capability versus component functionality; prototype functionality versus system capability; integrated system versus performance specifications; and system concepts and technology maturity versus defined user needs. Based on competitive prototyping efforts adjustments may be made to top-level requirements and revision may be made to the cost and schedule estimates.

The last three steps (steps 10–12) of the SE TD phase are the start of the Integrated System Design effort, where the system design transitions from system concept to an integrated system design. The PM needs to be mindful and understand the KPP of the system and continuously monitor cost, schedule, and performance [46].

a. Technology Development Phase Technical Reviews

Technical reviews conducted during this phase include the Prototype Preliminary Design Review (PPDR) and the Prototype Critical Design Review (PCDR), that support the competitive prototyping efforts and support the technical approach and program plans.

The System Requirement Review (SRR), the first of three reviews used to start integrated system design, ensures that the system under review can proceed into initial system development by verifying that system requirements are consistent with the materiel solution. According to the *DAG*:

> The SRR confirms that the user's operational requirements are sufficiently well understood and have been translated into system specific technical requirements to permit the developer (contractor) to establish an initial system level requirements baseline [46].

The System Functional Review (SFR) ensures that the systems' functional baseline is established, and can satisfy the requirements of the CDD. This review assesses the decomposition of the system specification to system functional specifications. It completes the definition of items below the system level. According to the *DAG*:

> The SFR determines whether the system's functional definition is fully decomposed to its lower level, and that [IPTs] are prepared to start preliminary design [46].

In addition, the SFR determines whether the system's lower-level performance requirements are consistent with the system concept, and whether lower-level systems requirements trace to top-level system performance and the draft Capability Development Document (CDD).

The Preliminary Design Review (PDR), according to the *DAG*, is:

> A technical assessment establishing the physically allocated baseline to ensure that the system under review has a reasonable expectation of being judged operationally effective and suitable. The PDR establishes the allocated baseline (hardware, software, human/support systems) and underlying architectures to ensure that the system under review has a reasonable expectation of satisfying the requirements within the currently allocated budget and schedule, [46].

The PDR determines if the subsystem requirements correctly implement the system requirements and it traces subsystem requirements to system design.

Technology Readiness Assessment (TRA), and output of the TD phase, is a requirement for regulatory information for all acquisition programs. The TRA assesses the maturity of Critical Technology Elements (CTE). CTE are technologies that are new or novel and that a system depends on to meet requirements in development, production, or operation. The TRA is a tool for assessing "program risk and the adequacy of technology maturation planning" [46]. The TRA scores the current readiness level of developed system elements, using defined Technology Readiness Levels (TRL).

b. Technology Development Phase Outputs

Some of the outputs from the TD phase include: TEMP; SEP; TRA; Inputs to the CDD and the Acquisition Strategy; and PDR Report.

3. Engineering Manufacturing Development Phase

Figure 21 shows that in the EMD phase "B," "C"[30], and "D"[31] people interact in attempts to complete the development of a system or increment of capability, reduce integration and manufacturing risk, integrate sub-systems, and design for producibility. Since it begins after the Milestone B decision this phase is considered the program initiation.

Figure 24 shows the SE process steps in the EMD phase. The SE process attempts to complete the integrated system design, any remaining initial system design, and reduce system level risk. Key to this phase is successful performance in integrated tests, developmental evaluations, operational assessments, and the use of Modeling and Simulation (M&S) in T&E.

The first SE step of this phase finalizes the detailed design of the system by evolving the component, or CI, design into system product baseline. The detailed design of the system includes all hardware and software components.

Step 2 involves the fabrication of hardware components and software coding, acquisition of other components (commercial, re-use, etc), and the assembly of the components. If a technology is not mature enough to use in the current iteration of the system, an alternate technology is identified, to mitigate the associated risk.

[30] From the Appendix, "C" phase people are also engineers. They are experts in the sub-system technical areas. The best "C" phase people often move to work in the "B" phase.

[31] From the Appendix, The "D" phase people are the leaders from the "A, B, and C" phases that understand the sub-systems and how they will interact when integrated into the whole system. They are determined to make the system work and will work night and day to achieve successful systems.

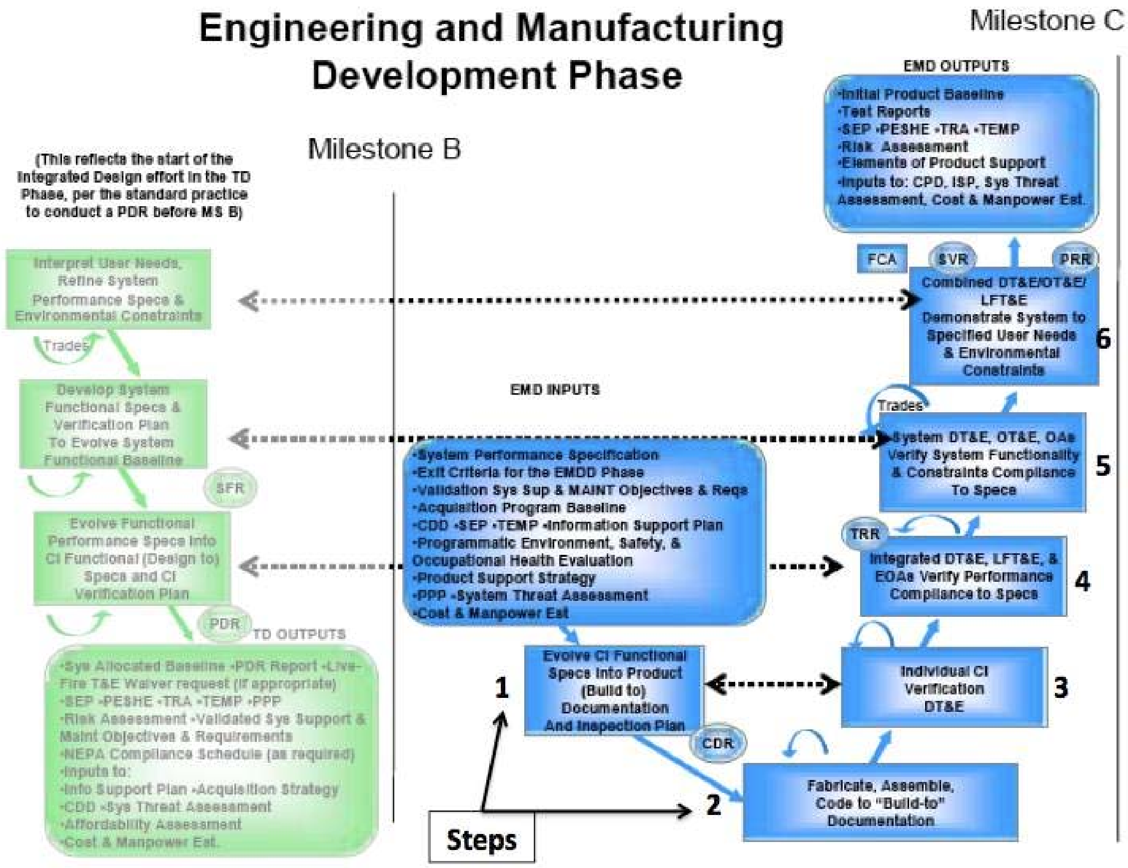

Figure 24. System Engineering Related Steps During the Engineering and Manufacturing Development Phase (From [46])

Step 3 evaluates individual CIs by conducting unit testing and evaluation of hardware and verification and validation of software. Components are tested in their operational environment. Risk, cost, and schedule assessments continue as mitigation solutions to integration, validation, and verification issues feedback to the refinement of the design.

Step 4 evaluates individual CIs by conducting unit testing and evaluation of hardware and verification and validation of software. Components are tested in their operational environment. Risk, cost, and schedule assessments continue as mitigation solutions to integration, validation, and verification issues feed back to the refinement of the design.

The next three steps (steps 5–7) conduct integrated tests that verify compliance to subsystem specifications, integrated system performance and functionality requirements, and integrated system verification against specified operational requirements. Risk, cost, performance, and schedule continue to be monitored. Any interface and interoperability issues for the system are continually addressed, in order to ensure that the system is able to achieve its interoperability certification. These steps confirm that the manufacturing processes are under control and any technical risks are mitigated.

a. Engineering Manufacturing Development Phase Technical Reviews

Technical reviews conducted during the EMD phase include the: Critical Design Review (CDR), Test Readiness Review (TRR), Functional Configuration Audit (FCA), System Verification Review (SVR), and Production Readiness Review (PRR).

The CDR is a technical review that establishes the initial product baseline, ensuring that the system can satisfy the requirements of the CDD. A CDR is normally conducted for each sub-system, or component, and culminates in a system level CDR that approves the product baseline for the entire system. There are incremental levels of CDRs, and they range from component, CI, to system level. The CDR evaluates the proposed "Build To" documentation to determine if it can start initial manufacturing. Once the product baseline is established the ability to change life-cycle cost or improve performance is reduced.

The TRR is a review that ensures that the sub-system or system is ready to proceed into formal testing. The TRR verifies the traceability of test requirements to user needs and also assesses the system for development maturity, cost, schedule and risk.

The SVR is a product and process assessment to ensure the system can proceed into Low-Rate Initial Production (LRIP) and Full-Rate Production (FRP). It evaluates cost, schedule, risk, and other system constraints.

The FCA tests characteristics of CI (hardware and software), attempting to verify that actual performance complies with design and interface requirements. During

the FCA, a review of the configuration item's test/analysis data is conducted to validate that the stated function or performance is met. A successful FCA demonstrates that an EMD product is sufficiently mature for entrance into LRIP.

The PRR determines if the program design is ready for production. It checks if prime contractor and its subcontractors have incurred unacceptable risks that affect production (schedule, performance, cost) of the project. The PRR verifies that system requirements are traceable to the final production system. The PRRs are conducted iteratively, and the "final" PRR should occur at the completion of the EMD phase and should asses the manufacturing and quality risk as the system proceeds into LRIP [46].

b. Engineering Manufacturing Development Phase Outputs

Some of the outputs from the EMD phase include: Product Baseline; Test Reports; TEMP; SEP; Inputs to the Capability Production Document (CPD), and Cost and Manpower Estimate.

4. Production and Deployment Phase

Figure 21 shows that in the PD phase "E"[32], "F," and "G"[33] people interact in attempts to achieve operational capability of the system in a way that satisfies the mission needs. The FRP Decision Review (FRP DR) separates the LRIP and FRP efforts. SE processes are used to reduce program risk and identify potential management issues in a timely manner. According to the *DAG*:

> As the integrated components develop into a system, the test and evaluation processes frequently reveal issues that require improvements or redesign. As the testing environment more closely approaches that of the users needs, the required improvements might be complex and/or subtle [46].

[32] From the Appendix, "E" phase people like to "clean-up" the system design by documenting configurations, developing end-user training documents, and cleaning up design issues. These people usually are writers and enjoy developing documentation, for example training documents, etc.

[33] From the Appendix, "F," "G," "H," "I," and "J" people are associated with life-cycle support, carry out production, ensure maintenance, perform upgrades, provide support, and who plan for retirement and disposal of the system.

Figure 25 shows the SE steps performed during the PD phase. In the first step, known system deficiencies (from all inputs available) are analyzed and a solution is proposed. A plan to build, modify, verify, test, and evaluate the system is formulated.

The next step takes the proposed solution to the deficiencies and translates them into hardware or software specification changes. Cost, schedule, and performance impacts are considered for the designed system, but a retrofit will also be considered because production of the system has already begun (system is in LRIP or FRP).

The last step verifies and validates the proposed changes as they apply to the current configuration of the system.

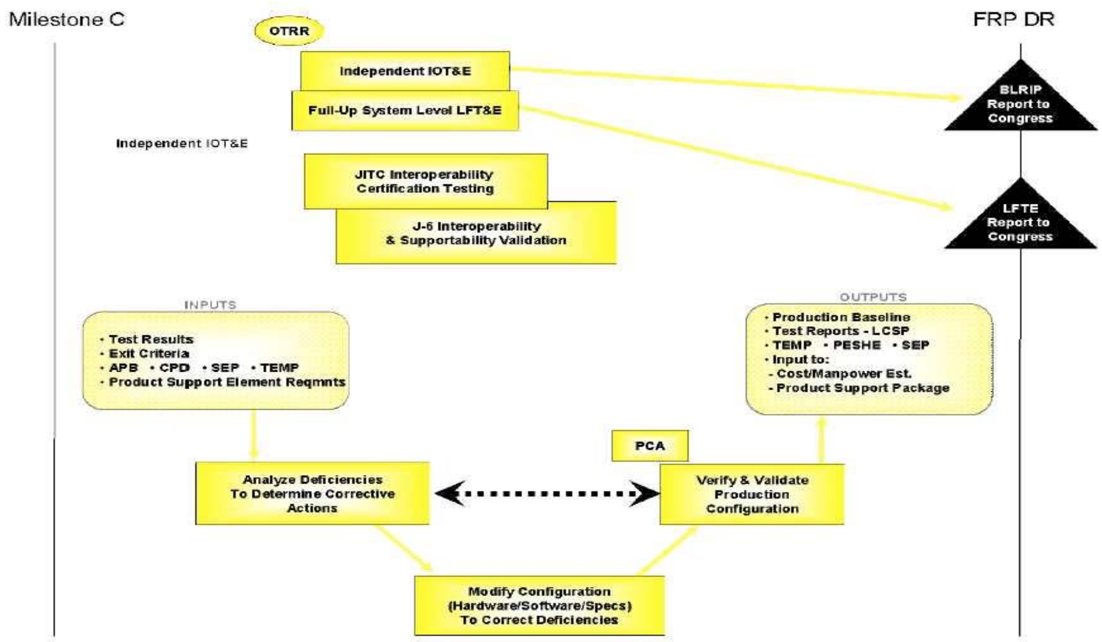

Figure 25. System Engineering Related Steps During the Production and Deployment Phase (From [46])

a. *Production and Deployment Phase Technical Reviews*

Technical reviews conducted during the PD phase include the: Operational Test Readiness Review (OTRR); and the Physical Configuration Audit (PCA). The OTRR ensures that the system can successfully proceed into IOT&E, a decision made by the Service Acquisition Executive. The FRP decision sometimes hinges on this technical review.

The PCA is conducted around the time that FRP begins, and it verifies that the related design documentation matches what was specified in the contract. The PCA also validates many of the supporting processes (manufacturing, quality control, testing, and training) that are used in the system production.

b. Production and Deployment Phase Outputs

Some outputs from the PD phase are: Updated Product Baseline; Evaluation results from test; TEMP; Life-cycle Sustainment Plan; and SEP.

5. Operations and Support Phase

The OS phase executes the support program that sustains the system in a cost-effective manner over the total life-cycle and eventually disposes of the system.

The SE process steps in the OS phase support in-service reviews where trade studies will be used to determine the best resolution to solve safety, readiness degrading, and improvement (modifications and upgrade) issues.

Figure 26 shows the SE steps performed in the OS phase. The first step monitors and collects service use data. Since many systems stay in service much longer than originally anticipated, operations and support decision will change as operational understanding of the system matures.

Step 2 analyzes data from problems that arise in the fielded system. As root causes are determined, potential solutions are developed.

The next two steps (steps 3–4) determine the system risk, the hazard probability and severity and also develop corrective action. The corrective actions, mitigation measures, can encompass hardware, software, support, materiel, or maintenance changes.

The next three steps (steps 5–7) integrate and test the corrective action to ensure that it solves the issue. In addition, they assess the risk of the improved system once corrective action is demonstrated as effective, and then long-range system ramifications and life-cycle costs are addressed.

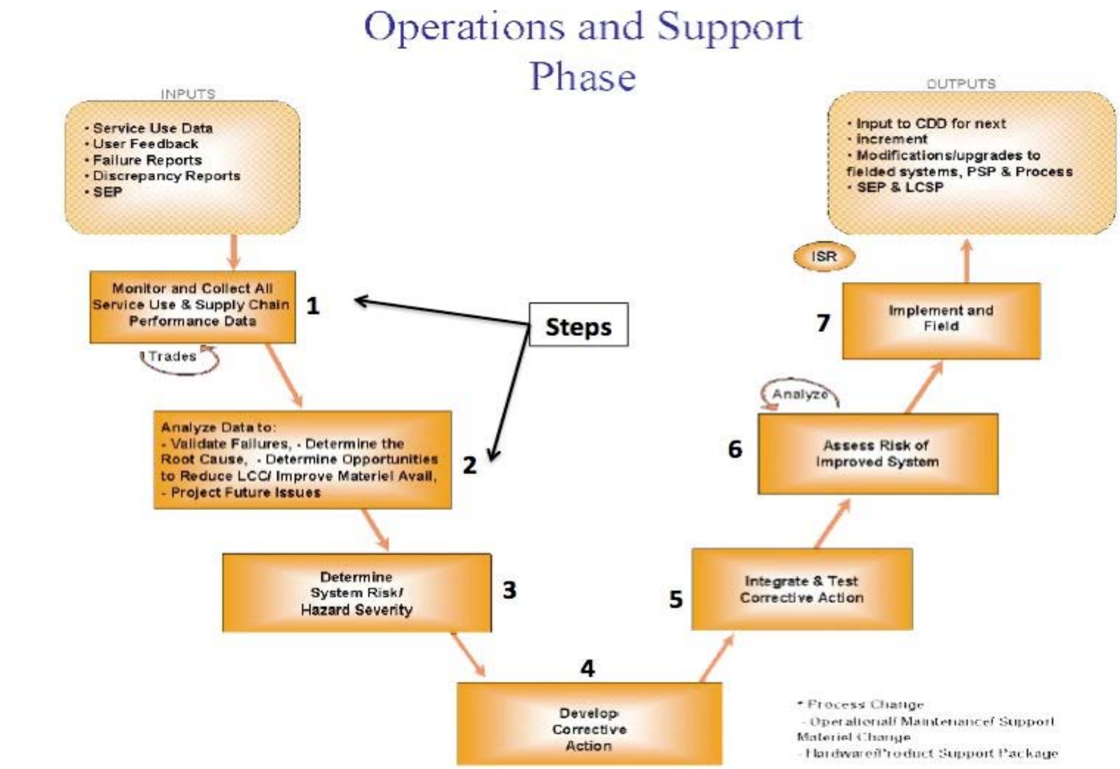

Figure 26. System Engineering Steps During the Operations and Support Phase (From [46])

a. Operations and Support Phase Technical Reviews

Technical reviews during the OS phase include the In-Service Review (ISR). The ISR assesses the in-service health of the system. According to the *DAG*, it:

> Provides an assessment of risk, readiness, technical status, and trends in a measurable form. These assessments substantiate in-service support budget priorities [46].

b. Operations and Support Phase Outputs

Outputs of the SE processes in the OS phase include: input to CDD for next design increment; Modification and upgrades to fielded system; data for ISR; and SEP.

D. CONCLUSIONS

This chapter has presented the SE approach to acquisition. Several different SE processes were discussed, and then a generic SE approach was mapped to the latest version of the DoD acquisition process.

The next chapter will present the Network-Centric Acquisition Process (NCAP) and will give a detailed description of the theories on which the NCAP are based, and describe how the NCAP will operate.

V. NETWORK-CENTRIC ACQUISITION PROCESS

The Network-Centric Acquisition Process (NCAP) will be presented in this chapter. Chapters I–IV have laid the foundation on which the NCAP will be built: network-centric theory, DoD acquisition process, and SE processes.

NCAP focuses on acquiring the "glue"[34] that makes networked systems network-centric. NCS range from a ship (LCS) to a large network (the GIG) to an unmanned aerial vehicle (e.g., the Predator UAV), the common thread that makes these systems network-centric is their ability to harness the power of the network to gain information and decision superiority over an adversary.

NCAP's goal is to deliver capability quickly to the warfighter, with the promise of follow-on fast incremental capability upgrades. Current DoD acquisition process is serial delivers large chunks of capability, it is expensive, has slow refresh cycles, and ensures that processes and systems be stovepiped. NCAP will provide the framework for faster acquisition by focusing on speed-to-capability, speed-to-better-capability, Valued Information at the Right Time (VIRT), component reuse, and Value Off-The-Shelf (VOTS) [49] [26].

NCAP is an SE based process where customers and developers work closely together to define the requirements, the development of products uses best industry practices and is iterative, and the integration of products is done in an environment that tests products frequently. The NCAP, as proposed in this chapter, is not currently used by DoD[35], but its successful implementation in the private commercial sector[36] is one of many compelling reasons for its adoption in the DoD.

[34] Network-centric "glue" is analogous to the network-centric infrastructure on which the NCS are able to achieve information superiority, decision superiority, and full spectrum dominance. The "glue" is the network-centric IT that supports NCS.

[35] The DoD has used aspects of the NCAP in Aegis combat systems software acquisition, but no evidence of DoD usage of a NCAP was found during research of this thesis topic.

[36] NCAP has been successfully implemented by Apple Inc. for applications used for the iPhone. eBay and Amazon have also successfully implemented NCAP.

The rest of this chapter will discuss the framework of NCAP, and then map the NCAP to the NCSE core diagram, which was presented in Chapter II. Then the chapter will describe in detail NCAP's parts, which include a set of evaluation metrics, component reuse, collaborative environment, acquisition data repository, electronic business marketplace, and Off-The-Shelf (OTS) components. Once the framework of NCAP is laid out, the last parts of this chapter will present a DAS level acquisition model for NCS[37].

A. NETWORK-CENTRIC ACQUISITION PROCESS AND THE NETWORK-CENTRIC SYSTEMS ENGINEERING CORE

The NCSE core diagram was presented in Chapter II, and was used to describe a SoS[38] that uses four approaches to achieve network-centricity. The NCSE core diagram is a useful way to understand how NCS operate. It is also useful in understanding how the NCSE's four separate approaches (top-down, bottom-up, middle approach, and disadvantaged user), are all integrated by the NCSE core (Networks, distributed computing, and real-time processing) into a SoS. This NCSE core will be used to recommend an NCAP framework.

The NCAP can also be regarded as a SoS that uses several framework approaches (data repository, electronic business (e-Biz) marketplace, development environment, etc.) that are all integrated to achieve network-centricity for the acquisition process.

Figure 27 shows the mapping of the NCAP onto the NCSE core diagram. The customer requirements[39], component reuse, data repository, e-Biz marketplace, and Government Furnished Equipment (GFE)[40] occur in the top-down approach. The network-centric applications created by developers, the development standards, and the

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[37] This model was developed by the Defense Science Board and recommended to replace the DoD Directive 5000.01 model [50].

[38] NCSE core is a SoS because it is made up of systems that can operate independently, but when integrated make the system network-centric. It could be argued that the top-down, bottom-up, middle, and disadvantaged user approach are all systems in the NCSE core, therefore making it a SoS.

[39] Customer requirements refer to the "network-centric" needs.

[40] Government furnished equipment (GFE) is equipment (hardware and/or software) that is made available to NCAP developers for their use in innovating and developing network-centric systems.

available Government OTS (GOTS) occur during the bottom-up approach. The push/pull of database search information, upload/download database items and e-Biz marketplace items, and financial transactions occur in the middle approach. The network-centric applications of non-vetted or non-interfaced developers and OTS components, exist in the disadvantaged user approach. This is because they are not easily able to get access to the NCAP, and therefore, acquisition of those network-centric applications is handled differently.

In summary, the recommended NCAP framework will have the following: metrics; component reuse; a collaborative development environment; a data repository; an electronic business (e-Biz) marketplace; OTS component use; open system and open license; and certification and IA processes. The chapter provides details on elements that comprise the NCAP framework.

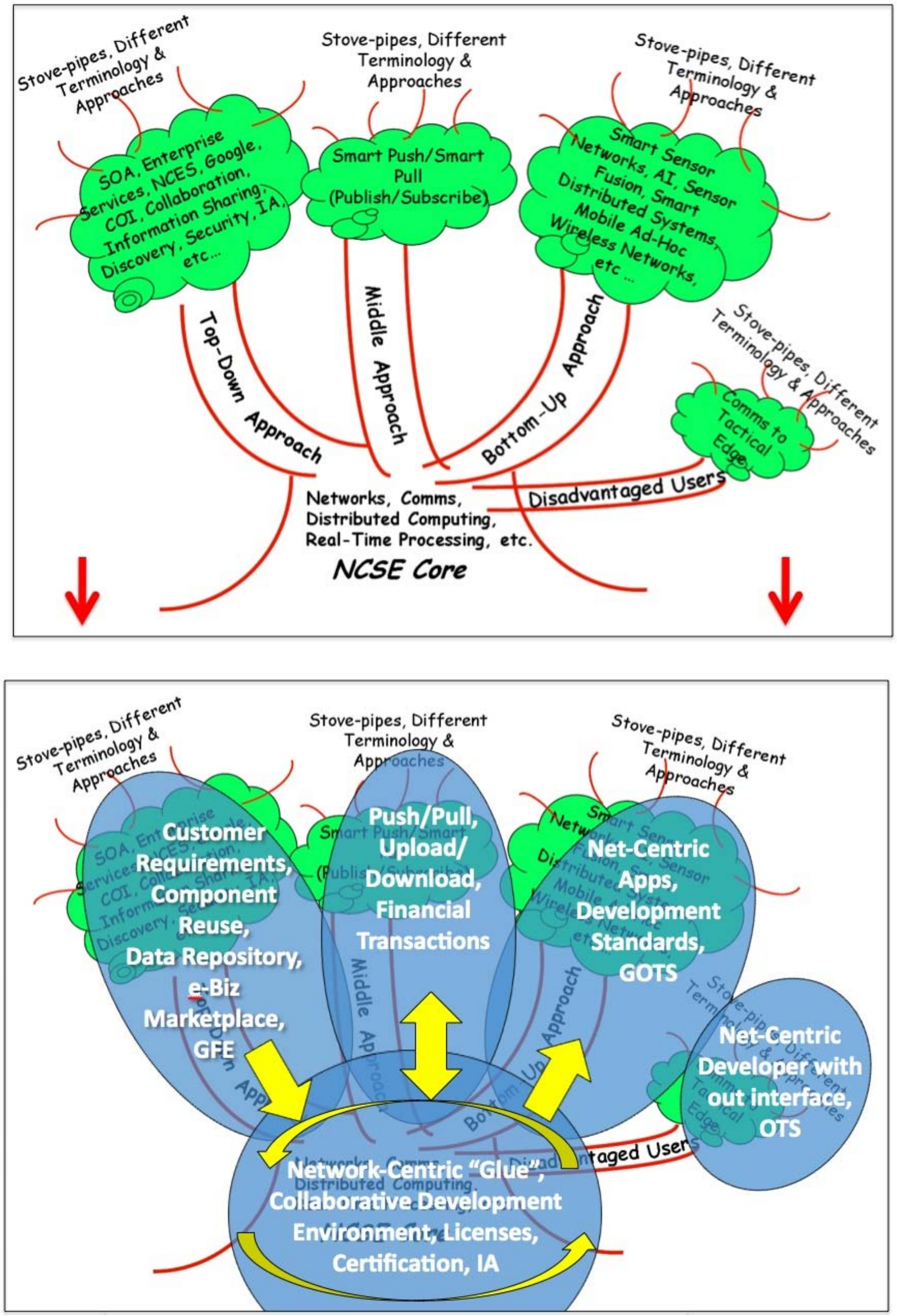

Figure 27. Mapping of the NCAP to the NCSE core diagram (From [27])

B. ACQUIRING THE NETWORK-CENTRIC "GLUE"

As discussed in Chapter I, NCS gain their effectiveness from harnessing the power of the connected network nodes and support. Therefore, as the number of nodes increase, Blue forces gain decision superiority over an adversary. Or, as Gunderson summarized the traditional NCW hypothesis, "[a] force with the most networked connectivity to relevant, timely, and accurate data is the most 'powerful' " [4].

Although NCS can be platforms, weapons, sensors, or systems, NCAP will focus on acquiring that which makes NCS network-centric, i.e., the network-centric Information Technology (IT). In other words, NCAP is about acquiring the network-centric "glue" that enables the network and support network-centricity. "Glue" is the integration of all parts in Figure 27.

C. NETWORK-CENTRIC ACQUISITION PROCESS OVERVIEW

The DoD is slow in delivering the required capabilities to the end-user, taking 10 to 15 years to get from program start to component production [51], and thus often delivering capabilities to the warfighter that are outdated or obsolete. This is reinforced by Bob Arbetter, Director, Collection Concepts & Strategies, Office of the Deputy Undersecretary of Defense for Intelligence, who said that "slow acquisition equals obsolete technology" [52]. In the current warfighing environment that includes the Global War on Terror (GWOT), it is critical to get up-to-date capabilities to the warfighter quickly. In order for the DoD to deliver leading edge technology to the warfighter, it needs to use an acquisition process that delivers needed capabilities faster, cheaper, and with frequent refresh cycles. NCAP is the solution that will change DoD acquisition from slow, serial, and massive, to fast, parallel, and incremental.

The next subsections will describe the qualities needed in the NCAP.

1. Fast Acquisition

NCAP can facilitate fast[41] acquisition by leveraging the reuse of existing technology, mandating use of "Open Modular Design" products [39] [53] [54], encouraging maximal use of Commercial OTS (COTS) products and enabling collaborative and open competition.

2. Parallel Development

Parallel development, vice serial development, attempts to address and correct the inefficient way in which DoD systems have been developed. As discussed in Chapter III, all DoD acquired systems go through the following steps: they are designed; built; tested; V&V; and supported throughout the system's life-cycle. Current DoD acquisition conducts each step in series (e.g., finish design of system, then build, then test, etc.).

Parallel development advocates implementing short iterative development cycles of the system acquisition steps almost in parallel (e.g., at the same time). Parallel development would specifically: design a segment of the system; build the segment; test the segment (e.g., for interoperability); V&V the segment; and develop the life-cycle support plan for the segment. Segments are then integrated incrementally, until the system is completed. Developing products in this way is efficient, because integration and testing of the system is conducted continuously throughout the development of the system, and therefore, integration and testing issues can easily be corrected with minor system modifications.

3. Incremental Acquisition

Incremental acquisition prioritizes timeliness of capability delivery over the amount of capability delivered. Incremental acquisition is made a reality by NCAP's frequent upgrade cycles.

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[41] Fast implies that the acquisition takes less time or less effort to complete. This statement is made with the assumption that the reuse of components, use of "open" products, maximal use of COTS products, and encouraging collaborative and open competition will foster an environment of innovation that spurns fast and efficient product development.

D. NETWORK CENTRIC ACQUISITION PROCESS METRICS

DoD acquisition is a business, and the business of providing "global security"—defense systems—is difficult, challenging, and complex, but it is important that it be carried out correctly. The complexities of DoD acquisition are not excuses for bad business practices. In industry, good business practices depend on managing a "dashboard"—measuring metrics—that link customer concerns with the processes that the enterprise or business can use to address them. Thus, the NCAP model should focus on delivering better capability faster. That is, not only improving speed-to-capability, but also improving the value of the capability delivered. Hence, the traditional jargon "speed-to-capability" becomes "better-speed-to-*better*-capability." The NCAP "dashboard" then seeks to objectively define, monitor, and adjust "better" with respect to required speed, and with respect to required capability.

The next two subsections will present two metrics that will be used with the NCAP.

1. Better Speed-to-Capability Metric

The DoD needs a metric to measure how quickly a capability is developed and fielded—"better" speed-to-capability. In the network-centric world, this metric measures the speed with which net-ready capabilities are developed.

The Defense Acquisition University (DAU) defines net-ready as a:

> [National Security System (NSS]) that meets required information needs, information timeliness requirements, has information assurance accreditation, and meets the attributes required for both the technical exchange of information and the end-to-end operational effectiveness of that exchange [and] enables [users] to exercise control over enterprise information and services through a loosely coupled, distributed infrastructure that leverages service modularity, multimedia connectivity, metadata, and collaboration to provide an environment that promotes unifying actions among all participants. [55]

Gunderson[42] et al. explain that traditional acquisition metrics are called "Key Performance Parameters" (KPP). The KPP traditionally used to define "Sustainability" is called "Operational Availability" with shorthand notation of A_o. They suggest that better-speed-to-capability is required to sustain an NCS throughout its life-cycle. Hence they abstract the notion of A_o to define a metric to measure speed-to-capability of net-ready systems they call A_{nr}[43], *availability* of net-ready capability [56].

Gunderson et al. have advocated using A_{nr} as a way to evaluate net-ready acquisition process-level Measures Of Effectiveness (MOE). A_{nr} measures the speed-to-capability of net-ready acquisitions, providing a metric that focuses on the network-centric acquisition priority of speed.

$$A_{nr} = DT_i / (CDT = (DT_c + TT_c + CT_c))$$

Where:

A_{nr} = Net-Ready Availability: a unit-less index that compares the obsolescence rate of the technology to how quickly the capability can be deployed and certified as secure and interoperable

DT_i = Initial estimated Development Time: calendar time required, in consideration of testing and certification time lines, to field an increment of IT capability prior to its obsolescence.

CDT = Capability Deployment Time: best current estimate of the total calendar time it will take from commencement of development until increment of IT capability is fielded.

DT_c = Current, or revised estimate of Development Time at the time of evaluation

TT_c = Current or revised estimate of Test Time: calendar time required post development to complete any additional required testing.

CT_c = Current or revised estimate of Certification Time: calendar time required post testing to achieve any necessary certifications. .

Figure 28. A_{nr} Defined (From [56])

42 Chris Gunderson, Captain (retired) U.S. Navy, is Principal Investigator of the Naval Postgraduate School W2COG and Netcentric Certification Office initiatives. He is also a Research Associate Professor in the Department of Information Science at Naval Postgraduate School.

43 A_{nr} is a number between 0.00 and 1.0. An A_{nr} value closer to 1.0 is always desirable, but impossible to achieve.

A_{nr} measures the ratio of the Initial Estimated Development Time (DT_i) over the Capability Development Time (CDT). Figure 28 explains how A_{nr} is calculated and defines all of its terms. A better way to look at the A_{nr} formula is:

$$A_{nr}=DT_i/CDT, \text{ where } CDT=(DT_c+ TT_c +CT_c)$$

A_{nr} measures the acquisition processes effectiveness at delivering speed-to-capability. Better stated, A_{nr} is a measure to compare technology obsolescence rates with capability development time, thus allowing the PM manager know if a product will be acquired that has obsolete technology[44]. Ideally:

- The Initial Estimated Development Time (DT_i) would be perfectly accurate, and
- Testing and Certification (TT_c and CT_c) would occur perfectly in parallel with development.

In that ideal case, DT_i and CDT would be equal and yield an A_{nr} of unity[45]. However, at any given phase of a realistic project, the revised estimate of CDT generally becomes larger than the initial development time estimate, DT_i. Therefore, as the increment of development progresses, the current calculated value of A_{nr} will likely decrease. If it decreases below a predefined threshold value, the program is in danger of missing its speed-to-better-capability goal, and must re-scope the deliverables accordingly. This metric is useful because it gives the PM or acquisition manager the ability to objectively evaluate the efficiency of the acquisition process to quickly field relevant (leading edge) systems.

Gunderson et al., suggest notionally that a good target value of CDT should be consistent with Moore's Law—eighteen months. A good target value for DT_i might be twelve months—the time it typically takes to field a pure COTS solution across a large

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[44] The equation itself does not directly address obsolescence rates. Assuming Moore's Law—eighteen months—is applicable, then the longer it takes to develop a product, the more likely it is that the product's technology will be obsolete.

[45] Even better would be if the revised estimate of Development Time were less than the original estimate! In that case A_{nr} would be greater than one.

enterprise. Those values yield a notional target value for A_{nr} of 0.66[46] [56] that should be the threshold value below which a PM should begin to consider alternative acquisition plans because the evaluated acquisition will deliver a product that is technologically obsolete[47].

The following two examples illustrate how to use A_{nr} to evaluate an acquisition decision.

a. Example One–Threshold Example

While a PM might set his *objective* at delivering his capability increment within one Moore's Law cycle of eighteen months, he might set his *threshold* at twice that time. In that case he might set (DT_i) at three years. He might estimate three years to for the current development time (DT_c), a year to test it (TT_c), and 6 months to certify it (CT_c). This results in a net-ready availability of:

$$A_{nr}= 3/(3 + 1 + .5) = 0.66$$

These values of A_{nr} and CDT are perhaps reasonable thresholds [56].

b. Example Two

Now suppose the same PM experiences delays similar to those of the Army's Future Combat System, say three years. Originally the PM allocated 3 years to develop the system (DT_i), a year to test it (TT_c), and 6 months to integrate it (CT_c). Taking into account the expected delay, the following values are entered into the equation: DT_i= 3 years; DT_c= 6 years (3 years original estimate + 3 years of delay); TT_c= 1 year; and CT_c= .5 years. Calculating gives: We recalculate:

$$A_{nr}= 3/(6 + 1 + .5) = 0.4$$

[46] Intuitively, the smaller A_{nr} is, the longer it takes to deliver a capability and the more obsolete the technology will be. The bigger A_{nr} is, the shorter it takes to deliver the capability and the more leading edge the technology will be.

[47] Technologically obsolete refers to systems that are more than one generation behind the most up-to-date technology (e.g., third generation iPod is obsolete because there is a fifth generation iPod on the market). The goal of the A_{nr} metric is to allow the PM to decide if he should continue acquiring a product that is technologically obsolete, or change acquisition strategy for a more technologically advanced product.

Based on which systems or components are available commercially, the PM can now objectively prove that his technology is already a generation behind the current—cutting edge—technology and will likely deliver obsolete technology. The PM can take action accordingly (i.e., cancel, down scope, deploy pure COTS patch, etc.), rather than the acquisition of a system that is obsolete [56].

Gunderson et al. recommend that A_{nr} of .66 should be used as a benchmark below which a PM should consider other options to deliver the capability [56]. The A_{nr} metric can also be used to track the reliability of the specific acquisition to deliver a capability before its technology becomes obsolete.

2. *Better* Capability Metric

Although A_{nr} measures speed-to-capability, another metric is needed that measures the value of the information delivered by the NCS. That is we need a metric to define "better" capability. NPS Professor Rick Hayes-Roth has developed an approach he calls Valued Information at the Right Time (VIRT) [26].

Gunderson et al. suggest that the metric to measure better-speed-to-better-capability is A_{iv}, i.e., information value availability, see Figure 29. This metric is the product of the Information Processing Efficiency (IPE) and the Delivered Information Value (DIV) [56]:

$$A_{iv} = \text{IPE x DIV}$$

a. Information Processing Efficiency (IPE)

IPE is a ratio of the Valued Bits processed (VB) over the Total Bits processed (TB) and multiplied by a perishability factor (W_p)[48]. Otherwise stated, this measures how valuable the received information (VB) is when compared to all the data

[48] Perishability factor describes a window of utility. The five-day forecast of a hurricane has a low perishability factor, while the pinpoint location of a tornado has a high perishability factor. W_p is a subjective value that needs to be carefully assigned by the PM.

received (TB) and how timely the data was delivered (W_p). IPE measures the value and timeliness of the information, or "how easily and effectively disparate data from disparate sources on network(s) are collected and bundled usefully together [57]."

A good analogy for IPE is a search for "weather forecast for Baghdad, Iraq" using google.com. Ideal IPE would yield a single result (VB = TB, and VB/TB = 1.0) that would take a fraction of a second to display (W_p=.99)[49].

$$IPE_{\text{Ideal Search}} = (VB/TB)x(W_p) = (1.0)x(.99) = .99$$

In a non-network-centric environment, the previous search would yield ten valuable results out of ten thousand results (VB/TB = 1/1000 = .001), in a fraction of a second (W_p=.99). Although the results would have a "relevance" ranking and delivered in a timely manner, the end-user would have to devote valuable processing time to decide which result is the desired one.

$$IPE_{\text{Non-Network-Centric Search}} = (VB/TB)x(W_p) = (.001)x(.99) = .0099 \text{ or } .01$$

Although the above example is simple, it clearly illustrates the power that analyzing the IPE of different systems can have on the final decision of what system to acquire.

$$A_{iv} = IPE \times DIV$$
$$IPE = (VB \div TB) \times W_P$$
$$DIV = P_1 \text{ X } P_2 \text{ X } \ldots\text{X } P_n$$

where:

A_{iv} = Information Value Availability
IPE = Information Processing Efficiency
VB = Valued Bits Processed
TB = Total Bits Processed
W_P = Perishability factor, i.e. describes time window of utility

DIV = Delivered Information Value

- $P_1, \ldots, P_n$ = Measured or target scores re operational performance, e.g., Probability of Kill, Planning Cycle Time, Logistics Latency, etc.

Figure 29. A_{iv} Defined (From [56])

[49] Wp=.99 was subjectively chosen, but since it was gathered fast and the information not very perishable, a value close to 1.0 was chosen. Highly perishable information would have a Wp closer to zero.

b. Delivered Information Value (DIV)

DIV measures operational performance (see Figure 29). Typically DIV is represented with traditional military Measures of Effectiveness (MOE) or Measures of Performance (MOP) like “Probability of Kill,” “Circular Error Probable,” “Fratricide” statistics, etc. For example if the “weather forecast for Baghdad, Iraq” turned out to be accurate, it would positively affect the probability of success of a military operational mission (where $P_{s\text{-initial}}$(Military Ops)=.50). The positive impact of the correct weather forecast would increase $P_{s\text{-initial}}$(Military Ops) say by 10%[50] to a $P_{s\text{-final}}$(Military Ops)P_s=0.55. If there were many factors contributing to the P_s, then the impact on each factor (P_1, P_2, …P_{n-1}, P_n) would be evaluated individually and then multiplied together to give DIV [57].

As stated earlier, the A_{iv} metric is the product of IPE and DIV (see Figure 29), and could be used to objectively compare different approaches to deliver the “network-centric glue” for a particular NCS to determine which delivers the greatest information value. The A_{nr} and A_{iv} metrics would be of value to many network-centric acquisition stakeholders as they evaluate different network-centric systems to acquire. These metrics would also useful for evaluating the development status (cost, schedule, performance) of a NCS and to decide if the acquisition should be cancelled, modified, or extended.

The next section of this chapter discusses the framework of the NCAP.

E. NETWORK-CENTRIC ACQUISITION PROCESS FRAMEWORK

In this section, the framework of the NCAP will be discussed. Although each part of the NCAP framework is presented individually, there is much overlap between the different framework parts. The overlap can be seen in Figure 27.

The central tenet of the NCAP is to provide not just “better” speed-to-capability but “better” speed-to-“better”-capability. The following sub-sections will describe how these are achieved by: maximizing the reuse of components; using a collaborative

[50] This example is to show that having the correct information would increase the probability of success. All the probabilities were randomly chosen to illustrate the use of this metric.

development environment (where providers innovate and develop); creating a data repository that contains all the data on NCS (design, software, hardware design, etc.); using an electronic business (e-Biz) marketplace (where customers and developers are matched and network-centric products are made available); where OTS product use is maximized; where open systems are available for innovation (open source, open architecture, and open license); and where developed items meet certification and IA standards.

1. Maximize Reuse of Components

Maximizing reuse of components is a solution to fast acquisition (speed-to-capability), but in order to mandate reuse across intellectual property domains, the DoD must own purpose rights to the designs and components[51]. The reuse of components can be seen in the top-down part of the NCAP framework of Figure 27.

Best practices of software development preach the reuse of software (be it source code, objects, or entire software programs) [50] [58]. NCAP framework encourages reusing software, systems, and components to the maximum extent possible because it reduces the acquisition time, since the reused items already exist and do not need to be created.

In order to facilitate and encourage maximum software reuse, network-centric stakeholders will need to define and implement requirements (e.g. standards) for network-centric interfaces, interoperability, software security, and development environments (e.g. Java, Windows, Flash). Therefore, the reuse of components that do not have standard interfaces, interoperability, and security would not be advocated. This is because the effort required by the developer to make the reused components compliant with network-centric standards could require modification that would destroy the cost savings that reuse could have afforded.

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[51] A discussion on government purpose rights as they apply to reuse follows later in this Chapter.

The current trend in DoD acquisition is to develop systems that use common components, that have standardized interfaces, and meet minimum IT security standards [46]. As older "legacy" systems are phased out of the DoD inventory, the newer NCS and their associated network-centric components (software systems with loose coupling and high cohesion) will become easier to reuse. The ease in reuse will be due to the way software systems engineering designs maximize object-oriented programming that allow for a developers to "pull" software objects or applications, adapt them, and "plug" them into the system they are developing.

The reuse of components will meet skepticism from many in the DoD and private industry. Most NCS SME consulted for this thesis agreed that reuse of components is good and will eventually become a standard practice. Some SMEs explained that developers will find it easier to develop the applications or objects required for the new system instead of taking the time to search for the item that can be reused. The crux of mastering the reuse issue—making it easier for developers to reuse network-centric components—is to be able to effectively catalog the network-centric components into a data repository that catalogs and stores components and allows for efficient search, download ("pull") and use or modification. The data repository will be discussed in detail later in this chapter, in section C.3; the next NCAP framework item discussed is the collaborative development environment.

2. Collaborative Development Environment

The central idea of the NCAP is to create an environment where network-centric products are developed using "best industry practices." This development environment would use open systems that are interoperable and that are developed in a competitive environment[52]. The idea of a collaborative development environment comes from best business practices of public sector companies like eBay, Apple (for iPhone), Google and Amazon. In these collaborative environments, developers have access to the open source

[52] Competitive environment refers to an environment like www.eBay.Developer.com where open source is made available to all members of the environment, and where they can compete with each other in developing a better application for eBay.

code, an Application Programming Interface (API)[53], and a language specific programming environment (Java, Flash, PHP, etc.). The collaborative development environment can be seen in Figure 27 as the integration part of the NCSE core (trunk) of the NCAP framework diagram.

In the collaborative environment, the developer is given standards for application functionality, interfaces, and security, but is left to figure out how to improve existing systems. If the application developed (e.g., component, software, systems) is successfully tested[54], V&V, and provides value to the "end-user" or customers, it is then rated in a "consumer reports" style format.

Interested consumers, or end-users, will read the "consumer reports"[55] review on available applications, try the applications out, and be able to make an informed decision on the purchase or acquisition of the system, component, or application.

The following sub-section presents an example of a successful development environment used in the commercial sector.

a. eBay Development Web Site

The eBay development center is a perfect example of the NCAP in use in the private sector. The eBay development site allows developers to use different development environments[56] to build applications that meet certain eBay specific application improvement requirements[57]. The user agreements for interface, compatibility, security, and coding are made available to the developers—the KPPs are clearly spelled out. The developers create an application that is evaluated for

[53] Application programming interface (API) is an interface in computer science that defines the ways by which an application program may request services from libraries and/or operating systems. [59].

[54] Testing refers to any developmental testing and evaluation (DT&E) and operational testing and evaluation (OT&E) that is conducted.

[55] This would be a DoD web version of the *Consumer Reports* magazine published monthly by Consumers Union. It publishes reviews and comparisons of consumer products and services based on reporting and results from its in-house testing laboratory [60].

[56] eBay calls the development environments "development centers," but there are four environments that a developer can use to create eBay applications (JavaScript, Flash, PHP, Windows, and Java).

[57] By requirements, eBay has many applications that run on its web site. Developers are given the choice to improve any of the many applications (selling, buying, listing products, etc.) that run on eBay.

compatibility and interface requirements, tested, and V&V. The application is then made available to eBay users to test and rate the application and then can either purchase it or use it. If the application is desirable to the end-users, it provides value and has the "ilities"[58] that end-users desire. There is a type of "consumer reports" available to the consumers that rates the different applications (on a scale of zero to five stars) and makes the purchase or use of an eBay developer center application much easier.

The next part of the NCAP framework discussed is the data repository.

3. Data Repository

An important part of the NCAP is the use of a data repository of software, data, systems, sub-systems, applications, and components. The data repository would be an open source "virtual library" where vetted developers[59] would go and pull items (component design, software, programming objects, etc.) and use the pulled items in developing systems, subsystems, or applications that meet current identified capability gaps. The data repository can be seen in the top-down part of the NCAP framework of Figure 27.

The data repository would ideally contain information on all DoD systems and sub-systems, with the data arranged in an easily searchable semantic and function based format. The data repository would have an advanced semantic search system that would facilitate search for items to be reused, or modified.

One caveat about the data repository is that the DoD generally does not own unlimited data rights, or government purpose rights (GPR), to the COTS items it purchases. In order to be able to make COTS items available as "open source" special contracts would need to be crafted for that purpose when and if potential return on investment warrants. However, by definition, "COTS" means out-of-the-box interoperability across commercial standards. Hence, it is clear that entering COTS

[58] "ilities" refers to availability, reliability, usability, portability, etc. Reference [61] has a full list of system quality attributes.

[59] Vetted developers refers to DoD and private sector personnel who understand the development standards (interoperability, security, etc.) of the NCAP and who have developed a trust relationship with the DoD.

component information into the data repository, regardless of the licensing rights, would provide some utility to developers. GPR will be discussed in a later sub-section of this chapter.

One proponent of the NCAP, Dr. Bob LeFande, suggested that the use of data repositories is how modern industries acquire their products. He stresses that the U.S. Government, the DoD, should always own the design data and software, with all applicable licensing rights, and therefore be made available to be reused, shared, and improved by all stakeholders [62].

If the data repository is correctly set up, with a detailed list of available items to reuse, and with an efficient search engine, then the data repository would provide VIRT to the developers using the repository. In other words, the same information processing methods that support NCW support network centric engineering. By having a well-organized data repository with a search capability, the developer would be able to find components to reuse quickly (i.e., a high A_{iv}).

Otherwise, a poorly catalogued data repository with a mediocre search engine would require the developer to spend more time processing data and trying to figure out what items to reuse. If the effort to find reuse items is too large, then the developer could choose to create their own item, foregoing the idea of reuse. Therefore, it is critical to be able to efficiently search and find reuse components. VIRT explains this in the next sub-section.

a. Valued Information at the Right Time

As already discussed in Chapter II, VIRT is a generic solution to the problem of how to assure that important information is passed along and unimportant data is not [26].

Although VIRT was earlier used to describe the effectiveness of NCS, it can be abstracted to measure the ability of the NCAP's data repository to deliver valued information to developers of NCS. Achieving VIRT from the data repository will require careful cataloguing, frequent updating, and detailed descriptions (semantic and ontologic)

of items entered into the data repository. In addition, for high-level cataloguing, the data repository could be organized by categories, similar to Communities Of Interest (COI), as in the Defense Information Security Agency's (DISA) Netcentric Enterprise Services (NCES) [63].

What follows is an example of a data repository that was created, and provided VIRT to its users.

b. SHARE a Prototype Data Repository

In 2006, the DoD, under the guidance of Program Executive Officer of Integrated Warfare Systems (PEO-IWS), established an ontology[60] based software repository called the Software Hardware Asset Reuse Enterprise (SHARE) that facilitated the reuse of combat system software and related assets [64]. The framework of the repository used two "search" processes consisting of a component specification search (based on descriptive entries) and ontology search (based on a conceptual search and its relationship to other components).

The component specification search database catalogued the description of the items in the repository, both metadata[61] and software behavior descriptions. The metadata provided specific information on how to use the software item, while the software behavior component specification complemented the metadata search shortcomings by giving behavioral data of the software objects [64].

The ontology search process included descriptions of the component's operational relationship that created different perspectives, or contexts, for examining the contents of the repository. The relationships often include the component's use in the existing system and how it mapped to the general system architecture [64].

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[60] Ontology, in the IT world, is a formal representation of a set of concepts within a domain and the relationships between those concepts. Ontology is used to reason about the properties of that domain, and may be used to define the domain [64].

[61] Metadata is "data about other data," of any sort in any media. Metadata may include descriptive information about the context, quality and condition, or characteristics of the data [64].

The authors of *Ontology-based Solutions for Software Reuse*, stated that:

> This enriched semantic [or descriptive] specification of the assets in the SHARE repository will enable users to more readily find resources that meet their needs in their context. [64]

The reason for creating a data repository is to facilitate VIRT for the reuse of components by network-centric developers.

The ideal NCAP data repository would be a grander instantiation of the SHARE repository that would include ontology for all DoD systems and include software, hardware, parts, architecture details, and drawings. The ideal data repository would be very onerous to create, difficult to maintain current, and costly to achieve.

c. Data Repository Way Ahead

In order for NCAP to begin making data repositories available, a prototype data repository model will have to be created, modeled on and use the SHARE repository data. As the NCAP is incrementally implemented throughout the DoD, the data repository would grow as NCS objects, elements, and software code would be carefully catalogued into the data repository[62].

It will take time to carefully and methodically catalogue and enter NCS objects into the data repository. A standardized procedure for cataloguing and verifying the accuracy of entries will need to be developed, by network-centric acquisition stakeholders, and articulated to the network-centric acquisition community.

An incremental and iterative approach to updating and using the data repository, should be used, beginning with the cataloging of targeted NCS, and then adding systems that will use the NCAP. Once the data repository is able to provide robust search and discovery capabilities, then a mass effort can be undertaken to catalogue all DoD NCS. The data repository will continue to grow as more NCS are developed using the NCAP.

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[62] C4ISR legacy equipment and other network-centric software equipment will eventually be uploaded into the data repository, but this will not be an NCAP implementation priority.

The next section will present the electronic business (e-Biz) Marketplace. The NCAP process needs an environment where consumers and developers can be matched in order to facilitate the acquisition, product reviewing, and capability-needs determination Although the e-Biz marketplace encompasses and uses many of the NCAP framework items discussed in this section, it needs to be discussed separately in order to fully understand its impact on the NCAP.

4. Electronic Business (e-Biz) Marketplace

A thriving market is a place where providers and consumers can effectively find each other, form mutually beneficial relationships, and close mutually lucrative transactions. The DoD needs a new environment, call it an electronic business (e-Biz) marketplace, where developers and consumers can come together for the purpose of acquiring and developing network-centric capabilities. The e-Biz marketplace can be seen in the top-down part of the NCAP framework of Figure 27.

Chris Gunderson, a SME on network-centric acquisition, stated that:

> What's needed is a net-ready market for continuously improving capabilities for sharing information and making better decisions more rapidly. In other words, we need an e-market approach to evaluate and build network architecture a little bit at a time [5].

For consumers of network-centric capabilities, the e-Biz marketplace would be a venue where they would be able to search and acquire network-centric products that meet their needs. If the network-centric capabilities do not yet exist, then the e-Biz marketplace would match consumer's needs with developers willing to produce a materiel solution to meet their need.

For developers of network-centric capabilities, the e-Biz marketplace would be venue where they would make their network-centric products available for acquisition by consumers. Developers would also be able to efficiently develop NCS for consumers by leveraging the utilization of open source equipment/software found in the network-centric data repository and by using the open and collaborative development environment of the NCAP.

Specifically, the e-Biz marketplace would facilitate the following:

- Finding providers of the needed capability, fellow consumers with similar requirements, consumers for the products being offered, and/or partners who's offerings compliment your own—i.e., a dating service (to be discussed later in this sub-section)
- An experimental venue for invention, bundling, T&E and V&V of potentially useful capabilities—e.g., SourceForge.net , Java.net[63], and Forge.mil[64]
- A method for evaluating various mature product offerings against each other with respect to important considerations– i.e. consumer reports
- A means to rapidly close transactions, transfer funds, and receive capability—e.g., Amazon.com, in addition Existing contract vehicles

An e-Biz marketplace portal supporting NCAP would provide a great service to a global community of distributed[65] developers and consumers of network-centric processing capability. The e-Biz marketplace would be an open source and open standards capability development arena where developers and consumers are matched, new capabilities are evaluated and rated, and where acquisition transactions can occur.

The following subsections present specific details of the e-Biz marketplace.

a. e-Biz Marketplace Rules

NCAP stakeholders will need to develop e-Biz marketplace operation, development, and security regulations so that all marketplace users know and are able to safely and confidently utilize the e-Biz marketplace.

The regulations governing the operation of the e-Biz marketplace would complement the ones created for the NCAP data repository. The e-Biz governing

63 SourceForge.net and Java.net are open source software development sites used for innovative development.

64 Forge.mil is a family of services provided to support the DoD's technology development community. The system currently enables the collaborative development and use of open source and DoD community source software.

65 Distributed refers to the ability to be distributed geographically throughout the globe, but connected via the NCAP framework.

regulations would also include guidance on how the acquisition contracting vehicles would operate and incorporate best business practices from the private commercial sector.

b. Matching Consumers and Developer—A Dating Service

The e-Biz marketplace would provide a service that would bring developers and consumers together. All users of the NCAP would create profiles in the e-Biz marketplace domain, and either enter their network-centric requirements[66] or their capabilities that are available for acquisition, into their profile. Developers would browse a list of unfulfilled network-centric requirements and choose a requirement to develop. Customers would browse a list of available network-centric capabilities, and ideally find the capability that meets their need, helping implement VIRT into the e-Biz marketplace.

Although the framework for the "dating service" is not detailed, and only presented with great abstraction, the desired outcome is to have a method for matching consumers and developers in an efficient and timely manner.

c. Vetted Developers

In order to make the e-Biz marketplace work effectively, developers would need to pass through a "vetting process" that would certify their ability to comply with the development rules and regulations of the e-Biz marketplace. The vetting process would, in essence, be a screening to ensure that the products developed were compliant with DoD development standards (e.g., ISO, IA, Security, etc.).

Vetting developers helps ensure that they are using industry best industry practices and maximize the IA compliance (confidentiality, integrity, and availability) of the developed system.

[66] Network-centric requirements, in this context, refers to the capabilities that the customer or end-user is looking to acquire.

Although this section only gives high level vetting criteria for developers, the vetting process would ultimately ensure that only trusted developers are allowed into the e-Biz marketplace. Therefore, developers wanting to participate in the NCAP would have to be "certified" (vetted) to become vetted developers.

d. Financial Transactions

Although not discussed in this thesis, a series of contract vehicles will need to be developed in order to correctly incentivize developers to participate in the e-Biz marketplace, and therefore in the NCAP. The contracting vehicles need to be devised in a way that they are flexible enough to support the agile NCAP.

5. Value off-the-Shelf

Value-Off-The-Shelf (VOTS) is an important part of the NCAP. OTS[67] products provide an affordable way to acquire needed capabilities with virtually no development time (they are already available and on-the-shelf), and are easy to use (plug and play), requiring little personnel training. OTS can be seen in the bottom-up (for GOTS) and disadvantaged user (COTS) parts of Figure 27.

VOTS is defined as follows:

> [an] approach at delivering "good enough"[68] capability fast enough to take advantage of the rapid advances taking place in the information technology market. This approach emphasizes reusing and bundling interoperable [OTS] components in an architecture optimized for Trusted VIRT. [5]

[67] OTS should be thought of as a product that is available commercially. It is "shrink-wrapped" in a package and is ready for use once it is out of the box.

[68] Good enough capability refers to the decision to field a network-centric system quickly, and by doing so, the PM is accepting a product that does not have all the desired capabilities, but good enough capabilities to perform the intended mission. Future upgrade or refresh cycles will be needed to deliver all the desired capabilities.

OTS consists of COTS and GOTS[69]. The argument for favoring a VOTS delivery process comes from the ability of OTS products to reduce the time and cost of implementing capability improvements. OTS leverages existing technology, which is not the same thing as reuse, and gives end-user a capability as soon as the system is set-up [5].

It is important to understand that when OTS items are entered into the data repository (ontology and semantic search parameters and uploaded applicable software and code) the item becomes GFE. There will be licensing issues with making OTS items GFE, with open source and open licenses that allow vetted developers to use and modify those items. The licensing issues are beyond the scope of this thesis, and will not be addressed.

Figure 27 shows how OTS is the disadvantaged user of the NCSE core diagram because it lacks the required security and interconnectivity, but once entered into the data repository (as GFE) it becomes part of the top-down approach. Conversely, GOTS is part of the bottom-up approach and can be uploaded to the data repository, but GOTS belongs in the disadvantaged user approach if it does not have the right legal interfaces to allow developers to modify and innovate with it (e.g., upload to the database repository).

a. Reuse Components versus Off-the-Shelf

The focus of the NCAP is to deliver "better" speed-to-capability and "better" speed-to-better-capability. The framework of NCAP advocates both the reuse of components and maximizing the use of OTS. When NCAP stakeholders are presented with a decision to acquire OTS components, or reuse existing components, the metrics (A_{nr} and A_{iv}) should be used to determine what approach to take.

[69] GOTS is a term used for software and hardware products that are either developed by U.S. Government agencies or by an external entity, but with funding and specification from the government end-user. GOTS software solutions can be shared amongst U.S. Government agencies without additional cost [65].

It is possible that the data repository will have COTS/GOTS, and they will be called GFE products in its database. Semantically it could be argued that it is reuse of a component vice OTS, but the real issue is that the developer received VIRT (through the use of the data repository) that helped in the development of a network-centric product.

b. Commercial and Government Off-the-Shelf

Using OTS products is advantageous to the DoD because, generally, OTS products are cheaper to acquire and do not require development time. There is time to adapt and integrate the components into the overall system. Thus with OTS, the speed-to-capability focus of NCAP is maintained.

In NCAP, the new paradigm will be for PMs to "buy down risk" to cost, performance, and schedule by consuming as much pure COTS or GOTS as possible. The PM will then document the gap between COTS/GOTS capability and total system requirement and invest his new development effort to close the gap. Of course when the PM does that, he should be sure to use a license model that clearly emphasizes government purpose rights for re-use.

c. Information Assurance in Off-the-Shelf Products

A gap between military requirements and COTS IT products will often concern the IA requirements. Typically COTS products are not especially secure. Therefore, DOD will need to invest in developing IA solutions that COTS vendors can easily bundle in their future offerings (this is the interface with the disadvantaged user in Figure 27).

A solution for the IA issues of OTS is not addressed in this thesis, but network-centric acquisition stakeholders will be able to use the metrics, presented earlier in this chapter, to determine if an OTS acquisition will be able to deliver the required capabilities, or if a solution using reused components delivers better speed-to-capability and better speed-to-better-capability.

In this and the previous sections, the concepts of software reuse, a data repository, and OTS are discussed. The next section discusses open systems, licensing rights, and Government Purpose Rights (GPR), which are important in continuing to be able to develop NCS that are delivered quickly and at a reasonable cost. Open systems and GPR are important in the NCAP framework because if innovation is expected to flourish, then developers will need to use open systems that have open source items to foster that innovation.

6. Open Systems and Government Purpose Rights

The DoD has been pushing open system implementation since 1994 [66]. The Defense Acquisition University (DAU) Continuous Learning (CL) Module *Modular Open Systems Approach to DoD Acquisition* (CLE 013) defines an open system as follows:

> [An open system] employs modular design, uses widely supported and consensus-based standards for its key interfaces, and has been subjected to successful validation and verification tests to ensure the openness of its key interfaces. [67]

Open systems, although not shown in Figure 27, are enablers that allow for the integration of the top-down, middle, bottom-up and disadvantaged user parts of the NCAP framework.

DOD Framework		
Type of Data Rights	Definition	Applies to
Unlimited Rights	Right to use and disclose the data publicly, in any manner and for any purpose and to permit others to do so.	Data created exclusively with government funds and certain types of other data delivered to the government regardless of funding.
Government Purpose Rights	Right to use or disclose within the government without restriction or disclose to third parties for government purposes only. Third parties cannot use the data for commercial purposes.	Data developed with a mix of government and private funds.
Limited Rights	Right to use or disclose data internally. No disclosure to third parties without written permission except under limited conditions (e.g., emergency repair)	Data pertaining to items, components, or processes developed at private expense.

Figure 30. Data rights in the Department of Defense Acquisition Framework (From [68])

Network-centric acquisition expects systems to be "open"[70] and that the DoD have "unlimited" purpose rights[71], given to the DoD as part of the acquisition contract. The purpose right applies mostly to the technical data and computer software, but could also apply to hardware designs. Figure 30 shows the different technical data rights that are seen in the DoD acquisition contracts.

A promising approach for DoD to manage its GPR is by specifying in acquisition contracts that it desires a GPR license. According to G. Tereschuk, a Patent Attorney with the U.S. Army Communications/Electronics Life-Cycle Management Command (CE/LCMC), a GPR is:

> an Intellectual Property licensing system that is available to DOD acquisitions. [GPR] lies somewhere between the broad Unlimited Rights license rights allowing unrestricted Government release of information

[70] Open refers to all of the following: open architecture (which allows all to see inside all or parts of the architecture without any proprietary constraints), open system, and open source (source code available to the general public with relaxed or non-existent copyright restrictions). When items are "open" developers can reuse and alter the item with little or no licensing restrictions [66].

[71] Government can not hold unlimited license rights. Commercial developers always retain some ownership of IP they develop.

> and the more restrictive Limited or Restricted Rights licensing rights that forbid most releases outside the Government. The [GPR] license affords the Government with a comprehensive set of non-commercial license rights blending the broad Unlimited Rights and more restrictive Limited or Restrictive Rights license terms. [69]

One great advantage of GPR is that it can enforce an open modular design via making GOTS available to developers and GFE[72].

According to the Defense Federal Acquisition Regulation Supplement (DFARS) Section 252.227-7103:

> [GPR] means the rights to—
>
> Use, modify, reproduce, release, perform, display, or disclose technical data within the Government without restriction; and (ii) Release or disclose technical data outside the Government and authorize persons to whom release or disclosure has been made to use, modify, reproduce, release, perform, display, or disclose that data for United States government purposes. [54]

Acquiring a GPR, by the DoD, for acquired items, ensures that the DoD will not be held "hostage"[73] to the system designer for the life cycle of the system and that future iterations of the system can be worked on in an open, collaborative and competitive environment that fosters innovation.

7. Certification and Information Assurance of Network-Centric Products

IA concerns are not specifically addressed in this thesis, thus it is important to state that under the NCAP, guidelines for component certification and IA will need to be developed by NCAP stakeholders. These guidelines will need to be clearly understood by developers and effectively communicated to all network-centric acquisition stakeholders. This will ensure that developers are able to produce systems that meet

[72] The data repository would make GFE available to the developers for their use and integration into NCS.

[73] Hostage refers to possible high costs paid by the DoD to change systems for which it does not own the licensing right. Effectively being held hostage by the license rights owner.

certification and IA requirements for those systems. Certification and IA integrate the top-down, bottom-up, middle approach, and disadvantaged user to the NCSE core (the trunk) of the NCAP framework (Figure 27).

8. Relating NCAP Framework

The NCAP framework, as related to the NCSE core (Figure 27), is made of several systems and approaches (e.g., processes) that overlap and integrate in order to operate effectively. For example, a critical process is the need to reuse components (components are the network-centric applications in the bottom-up approach and the components from the data repository in the top-down approach of Figure 27). In order to reuse components and innovate, a collaborative development environment is needed where the reused components can be modified, tested, and if needed integrated into new systems. The data repository is another core part of NCAP (part of the top-down approach of Figure 27) that has the components that can be reused. In addition to the data repository, the e-Biz marketplace provides a marketplace (for sale of network-centric applications) and dating service (to match customers and developers); this is part of the top-down approach of Figure 27. Components can also be acquired through an OTS process (disadvantaged user in Figure 27). The network-centric "glue," open systems, open license, GPR, certification and IA enable the NCAP and make up the core part of Figure 27 that integrates all the branches.

The next section of this chapter will present the recommendations of a study by the DSB for the implementation of an acquisition model for IT that will replace the DAS model presented in Figure 13 of Chapter III. This is being presented as a foundation for NCAP and DoD Directive 5000.01 recommendations.

F. ACQUISITION MODEL FOR NETWORK-CENTRIC SYSTEMS

The NCAP is a SE based process that can be used to develop network-centric components. Chapter III discussed DoD acquisition, and presented in detail the Little "a" acquisition process, see Figure 9.

The framework for NCAP gives a "close-in" view of how network-centric acquisition will work. Stepping back and looking at the NCAP at the DAS level, it is clear to see that the current iteration of the DAS (Figure 13) does not support NCAP. The current DAS model is slow, serial and designed to acquire large military systems. The NCAP framework requires a fast, parallel, and iterative approach to acquisition.

A recent report by the Defense Science Board[74] stated that:

> The conventional DOD acquisition process is too long and too cumbersome to fit the needs of the many systems that require continuous changes and upgrades. [50]

In the same report, the DSB, recommended that a new acquisition and requirements development process for IT systems be developed. The DSB provided an acquisition process that is modeled on commercial best practices [50]. The new IT acquisition process proposed by the DSB is shown in Figure 31, and can be incorporated easily into the NCAP framework even though the DSB proposed model focuses on IT acquisition, while this thesis focuses on NCS acquisition. The new acquisition process fits the NCAP framework because they both focus on fast, parallel, and iterative development. In addition, the NCAP process focuses on acquiring the "glue" of network-centricity—described earlier as network-centric IT.

For brevity and ease of use, the new acquisition and requirements development process for IT will henceforth be referred to as the "Network-Centric System Acquisition Model" (NCSAM).

The following subsection describes, at a high level, the operation of the NCSAM.[75]

[74] The DSB provides independent advice and recommendations to senior DoD personnel on scientific, technical, manufacturing, acquisition process, and other matters of special interest to the DoD (http://www.acq.osd.mil/dsb/charter.htm).

[75] For more detailed understanding of the NCSAM, read Chapter 6 of the DSB report [50].

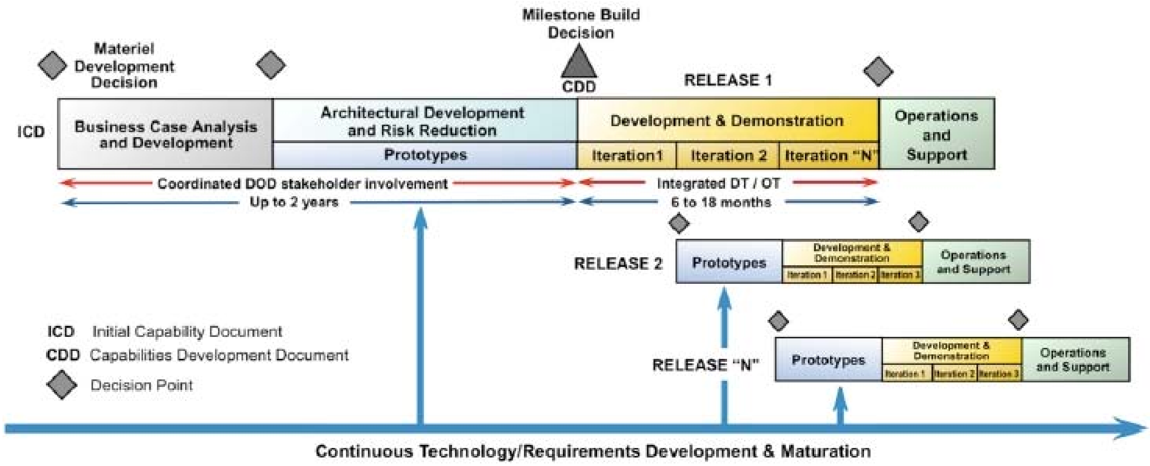

Figure 31. New Acquisition and Requirements Development Process for IT Systems or Network-Centric System Acquisition Model (From [50]).

The NCSAM is an agile process that is focused on delivering capabilities in 18-month increments, and leverages the advantages of modern IT practices [50]. NCSAM is divided into four phases and each phase begins with a decision point that requires MDA approval.

The first two phases of the NCSAM the Business Case Analysis and Development (BCAD) phase and the Architecture Development and Risk Reduction (ADRR) phase are very similar to the MSA, TD, and EMD phases described in Chapter III. The noticeable difference is that the NCSAM model exits the Milestone Build Decision (similar to Milestone B decision) with an acquisition strategy and acquisition program baseline for a certain number of capability releases, and with full funding for all future releases[76].

The next phase, the Development and Demonstration (D&D) phase builds and delivers operational capability for a set number of releases. For each release, the PM updates the system design and must receive MDA approval prior to beginning each iterative release. After three iterations of a release and a successful IOT&E and positive decision by the MDA[77], the system is fielded [50].

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76 Full funding for all releases means that funds are appropriated for all approved iterative releases of capability, thus reducing the risk of funding cuts in subsequent budgeting years.

77 The positive MDA decision is based on meeting all the requirements for the specific release.

Subsequent releases will have to again go through an MDA decision point, in order to ensure that the future releases are based on mature technologies, have an acquisition strategy and baseline approved by the MDA, and remain fully funded.

The last phase is the Operations and Support (O&S) phase that is very similar to the OS phase described in Chapter III.

G. CONCLUSIONS

The NCAP, as proposed, would incorporate all that was discussed in sections A thru C of this chapter, and use the acquisition model proposed by the DSB [50] and briefly described in section D of this chapter. The focus of the NCAP is to facilitate the speed-to-capability and speed-to-better-capability of network-centric applications by acquiring the "glue" of network-centricity. By favoring speed-to-capability, NCS would be able to take advantage of cutting edge technology, because with short development and release cycles, the technology would not be obsolete when it is ready to be deployed to the warfighters.

In summary, the NCAP

- can be related to the NCSE core tree diagram
- focuses on reuse of existing components that reduce acquisition development time
- maximizes the use of collaborative development environments that advocate open source and competition
- uses a data repository used to search for existing items to reuse
- uses an e-Biz marketplace to transacts its business, to match consumers and developers, and review products
- advocates the use of OTS products by encouraging PM to buy down as much capability risk with OTS
- provides open systems to developers as GFE and maximizes GPR in contracting language
- uses regulation to facilitate certification, V&V, testing, and IA for developed applications.

It is important to note that the NCAP is network-centric and facilitates network-centric "business" operations. The NCAP framework can be mapped back to the central tenets of NCW, discussed in Chapter II, to show its network-centric nature. Figure 32 is a visual description of NCW, where the info-structure supports a series of concentric rings of network-centric capabilities that ultimately support full spectrum dominance.

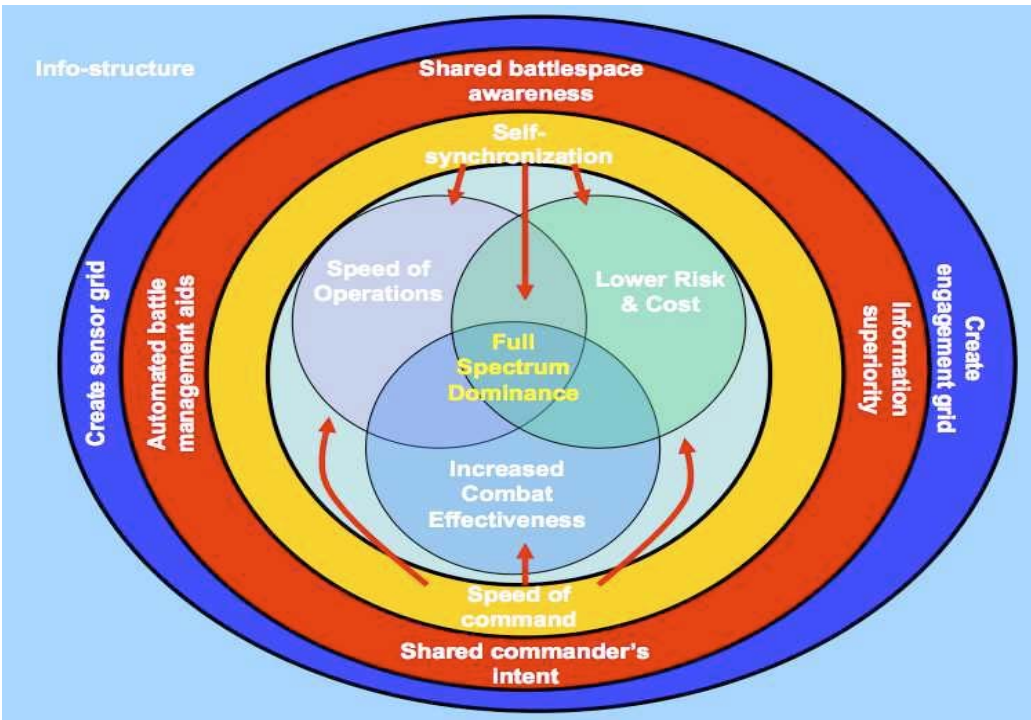

Figure 32. Network-Centric Warfare Framework (From [70])

The reuse of components facilitates product development and is analogous to "speed of command" in Figure 32. The collaborative development environment is analogous to the "info-structure" and "shared battlespace awareness" of Figure 32. The data repository is analogous to the "information superiority" of Figure 32. The e-Biz marketplace is analogous to the "shared battlespace awareness" and "shared commander's intent" of Figure 32. The use of OTS, GFE, and open systems is analogous to "speed of command" of Figure 32. The NCAP regulations for certification, V&V, testing, and IA are analogous to "shared commander's intent" of Figure 32. Lastly, the users of NCAP will have innovative products that are analogous to "self-synchronization" of Figure 32.

The NCAP, if implemented and scaled correctly, would deliver “good enough” capabilities to the end-user faster, with more frequent incremental capability improvements, and at a reduced cost.

The NCAP should be adopted by the DoD and used in conjunction with the DSB proposed NCSAM. Using the NCAP in the DoD acquisition framework of the NCSAM would help deliver “better” speed-to-capability and “better” speed-to-better-capability.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. THESIS OVERVIEW

This thesis has covered a wide swath of information from the network-centric world, and has applied it to a narrow part of network-centric acquisition, specifically introducing and detailing the Network-Centric Acquisition Process (NCAP).

The chapters of this thesis were structured in a manner that would support the presentation of the NCAP. Chapter I provided an overview of the thesis, discussed the underlying reasons for developing the NCAP, and the expected benefits of the study. Chapter II gave an overview of network-centricity, describing its origins, the underlying theory, and defining what a Network-Centric System (NCS) is. Chapter III gave an overview of Defense Acquisition and described in detail its different parts (PPBES, JCIDS, and the DAS). Chapter IV presented several different SE approaches, described in detail a generic SE approach to acquisition, and mapped the generic SE approach to acquisition to the DoD acquisition process. Based on the foundations of Chapters I–IV, Chapter V presented the NCAP and a detailed explanation of its framework. This Chapter gives conclusions and recommendations.

B. CONCLUSIONS

In order to correctly enable Network-Centric Warfare (NCW), the DoD needs to acquire NCS that continue to provide “better” speed-to-capability but “better” speed-to-better-capability. NCS are very diverse and can range from a large ship, to a small unmanned aerial vehicle, but the common thread that makes them network-centric is their ability to harness the power of the network to gain information and decision superiority over an adversary. What allows NCS to harness the power of the network is the backbone of Information Technology (IT) software. The NCAP provides an efficient and effective way to acquire the IT software backbone, or network-centric “glue,” that enables network-centricity.

The current DoD acquisition system is slow, serial in nature, delivers large “chunks” of capability at once, is expensive, has slow refresh cycles, and encourages stovepiped processes and systems to exist. The urgency of GWOT makes it critical to improve the DAS so that it can anticipate threats and quickly respond to those threats via the fast development and fielding of new capabilities. The NCAP provides an alternative for faster acquisition, by focusing on delivering “better” speed-to-capability and “better” speed-to-better-capability while incorporating current DoD network-centric guidance and industry best practices.

The NCAP framework incorporates metrics that measure the processes’ ability to deliver “better” speed-to-capability and better speed-to-“better”-capability. The framework also incorporates industry best practices such as component reuse, collaborative environment, acquisition data repository, electronic business marketplace, and OTS components.

The implementation of the NCAP will require fresh interpretations of DoD Directive 5000.01, the Federal Acquisition Regulations, and other governing directives. The DSB, in one of its 2009 reports, proposed new acquisition and requirements development process for IT (see Figure 31) [50] and was referred to in Chapter V as the Network-Centric System Acquisition Model (NCSAM). The NCSAM will provide the ideal framework on which the NCAP can operate because it supports quick iterative development cycles with frequent capability upgrades.

C. RECOMMENDATIONS

The following recommendations are made in order to help improve DoD acquisition of NCS.

1. Develop and Field Test the Network-centric Acquisition Process

The primary recommendation of this thesis is that the NCAP, whose framework was presented in Chapter V, should be adopted by the DoD in its acquisition of network-

centric capabilities. The adoption of the NCAP should be done in a small-scale, acquisition environment, or prototype venue, and then slowly, and iteratively, scaled to larger acquisitions.

The concepts and theories for the NCAP framework were taken from industry best practices, but these concepts need to be verified to ensure that they work in a DoD acquisition framework. It is recommended that the NCAP be used on a small acquisition, be it a test scenario, and then expanded if successful acquisitions are achieved.

When implementing the NCAP, it will be important to use the NCAP metrics, discussed in Chapter V, that measure "better" speed-to-capability, A_{nr}, and better speed-to-"better"-capability, A_{iv} as a means to objectively evaluate the acquisition.

It is expected that the NCAP will not be implemented with its framework fully operational (i.e., data repository, e-Biz marketplace, or development environment working), but this should not slow or halt the implementation of the NCAP, because it will be evolutionary. As NCAP framework items become operational, they should be incorporated into the operational version of the NCAP.

2. Change the Operation of the Defense Acquisition System, DoD Directive 5000.01

DoD should implement the recommendations of the Defense Science Board (DSB) March 2009 report, *Department of Defense Policies and Procedures for the Acquisition of Information Technology* [50], that recommended that DoD Directive 5000.01 use a new acquisition process for IT, called NCSAM framework in Chapter V (see Figure 31).

By implementing the DSB recommendations, the DoD will give the NCAP an acquisition framework that will enable fast, iterative, and agile acquisition.

3. Long-term Development of the Network-Centric Data Repository

The DoD should begin creating a network-centric data repository that mirrors the search and ontology structures of the SHARE repository, described in Chapter V and in *Ontology-based Solutions for Software Reuse* [64]. The creation of the data repository will need to begin slowly and on a small scale.

The creation of the data repository will be a challenging and difficult task. It will require clear and well thought out guidance on how to enter, classify, and store repository items. It is possible that the network-centric data repository will not be operational until several iterations, with a prototype NCAP data repository, are completed.

4. Framework of Network-Centric Collaborative Development Environment

Further studies should be conducted by the DoD to determine the best framework to use in the network-centric collaborative development environment. The framework will include the development environment to use, the standard software interfaces, the minimum IA requirements, and the licensing rights requirements.

Forge.mil should serve as a model, prototype, or even as the development environment to be used when implementing the early versions of the NCAP.

5. e-Biz Marketplace Structure and Business Rules

Further studies should be conducted by the DoD to determine the best framework to use in the e-Biz marketplace. The requirements for the e-Biz marketplace were discussed in Chapter V, but consultation and collaboration with e-Biz marketplace industry leaders (e.g., eBay and Amazon) could help create an effective DoD e-Biz marketplace, or prototype, on which to test the NCAP.

6. Network-centric Acquisition Stakeholder Education and Training

DoD should use the material in this thesis and references to create a course that would help educate DoD acquisition stakeholders on network-centricity, the DoD

acquisition process, and the NCAP. The Naval Postgraduate School could plan on using this thesis and references for course material in the Network-Centric Systems Engineering courses.

This thesis has covered a wide array of information, starting with network-centricity, to the Defense Acquisition Process, through Systems Engineering, and finally into the NCAP. The NCAP is a new and revolutionary process for acquiring network-centric systems, but it needs to be tested in order to objectively know if it will deliver on its promises of speed-to-capability and speed-to-better-capability. What is certain is that NCAP is critical for network-centric warfare and network centric operations in this time of Global War on Terror.

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APPENDIX: GENERIC SYSTEMS ENGINEERING APPROACH

A review of the SE processes standard and capability model, discussed in Chapter IV, Section C, shows that, although each is essentially different, all are very similar because the general underlying process is a common thread through all of them. An important part of SE is the use of multidisciplinary Integrated Product/Project Teams (IPT).

According to the *DoD Integrated Product and Process Development Handbook* [71], an IPT is:

> a multidisciplinary group of people, who are collectively responsible for delivering a defined product or process. The IPT is composed of people who plan, execute, and implement life-cycle decisions for the system being acquired. It includes empowered representatives (stakeholders) from all of the functional areas involved with the product—all who have a stake in the success of the program, such as design, manufacturing, Test and Evaluation (T&E), and logistics personnel, and, especially, the customer. Because the activities relative to a system's acquisition change and evolve over its life-cycle, the roles of various IPTs and IPT members evolve. When the team is dealing with an area that requires a specific expertise, [a Subject Matter Expert (SME]), the role of the member with that expertise will predominate; however, other team members' input should be integrated into the overall life-cycle design of the product. Some teams may assemble to address a specific problem and then become inactive or even disband after accomplishing their tasks.

The IPTs help effectively translate user-defined capabilities into operational system specifications that are consistent with cost, schedule, and performance constraints. IPTs facilitate meeting cost and performance objectives from product concept development through production, including field support by using the key tenet of multidisciplinary teamwork. Multidisciplinary teamwork allows for more effective communication between stakeholders, so that project decisions can be made more efficiently and effectively with an understanding of overall system impact. IPTs are crucial in the SE approach because they allow the stakeholders to effectively communicate and resolve issues that if not addressed early in the design process can have a negative impact on the cost, schedule, and performance of the system.

Figure 33 shows a generic SE model with a view of the ideal level of effort (work) and duration of the different SE process phases. Each phase is explained, along with "ideal" people type per phase[78]. This model will be used as the generic model which other models could be transposed on and related.

A. "X" PHASE—THE IDEA

The acquisition process begins with a need by a customer, "X" in Figure 33. "X" is the big idea, concept, or dream, of a system and consists of a generic top-down view.

1. "X" Phase People

These people are the "big picture" thinkers, visionaries, and dreamers. "X" people take the end-user needs, analyze them, and are capable of correctly describing the capability gap—the need—that requires a materiel solution. Since they understand the "big picture," they do not concern themselves with the intricate details of the systems they require.

B. "A" PHASE—CONCEPT DESIGN

The big picture architecture, top-down view of the system, is developed in the "A" phase of this SE process. The system developer takes the customer's need "X," and translates them into a concept design and preliminary architecture design, which help define stakeholder requirements. Correctly eliciting system requirements early in the process, can help reduce the overall cost, determine a more accurate schedule, and ensure desired performance of the system. Careful coordination is required among the stakeholders to ensure that conceptual design tradeoffs are correctly analyzed and implemented, and that defined requirements and concepts are properly documented. In this phase, concept design and agreement of the acceptance test is carried out.

[78] This SE model and "ideal" people types was developed by Dr. Lawrence Goshorn in the 1960s as the Chairman of General Automation Incorporated. This is a different perspective on the SE model described by ISO/IEC 15288, Blanchard and Fabrycky, and Buede [72] [73].

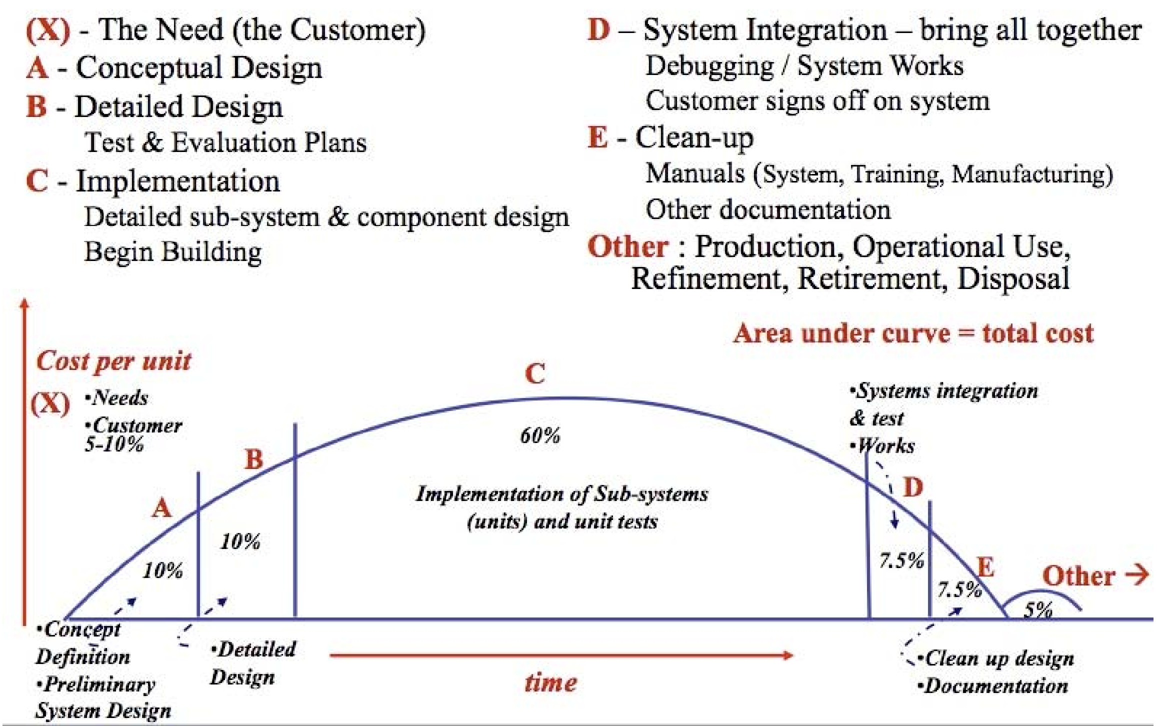

Figure 33. Overview of Systems Engineering Phases with Cost and Time (From [74])

1. "A" *Phase* People

"A" people interact constantly with the customer, "X" types, thus "A" people usually have marketing, business, and detail design experience[79]. "A" people need to be able to effectively communicate with the customer to correctly elicit the system requirements. "A" people need to also interact with "B" people, to make sure what they plan is technically feasible, and therefore "A" people with technical backgrounds (typically were a "B" person previously) are more successful.

C. "B" PHASE—DETAILED DESIGN

The "B" phase takes big picture preliminary system design architecture and breaks it up into system, sub-system, component, and system detailed specifications (e.g., turns architectures into detailed engineering, physics, terms, specifications, etc.). The detailed design phase, or detailed architecture design phase[80], uses the concept design

[79] Design experience refers to technical understanding of the type of system to be developed.

[80] Preliminary architecture is done in the "A" phase.

from “A” phase to create a detailed system design. Exact specifications for the system, its sub-systems, and interfaces emerge and the bottom-up engineering details are created using the top-down architecture (from “A”) and the details of how the top-down and bottom-up designs will be integrated. Rapid prototyping is done in this phase.

Test and evaluation plans are created, and detailed acceptance tests are specified, in order to show the stakeholders that the “X” phase needs are met.

1. “B” Phase People

“B” phase people are engineers with technical experience that push the technology boundaries with a “can do” attitude that is at times overly optimistic. “B” people interface with “A” and “C”; therefore they need to technically commit to “A” and make sure the plan is feasible for “C” people and encourage “C” people that this system is doable (show them the system vision).

2. “C” Phase—Implementation

This phase begins implementation of the system design as detailed sub-system designs are finalized and sub-systems are built. The majority of the work is conducted during this phase as the system(s) are built at a certain rate over time. The qualification system for the acceptance tests is further designed (from the detailed acceptance tests design from “B”) and implemented in this phase. At the end of “C,” each subsystem and the qualification system is tested.

a. “C” Phase People

“C” phase people are also engineers. They are experts in the sub-system technical areas. The best “C” phase people often move to work in the “B” phase.

3. “D” Phase—System Integration

System integration involves the integration of the built sub-system(s) to make up the whole system. During integration, debugging of the system is conducted on the

designed and built systems, and testing is accomplished through the acceptance test, to show that the designed and built system works, and that it meets the stakeholder's requirements.

The people from the "A, B, and C" phases are involved in the debugging of the integrated system in the "D" phase. The pace of this phase is fast and hectic because of the "unknown" and "known" issues that develop as the systems are integrated, and the timeline for product delivery gets tight.

The integrated system is demonstrated to the stakeholders, in order to ensure that the requirements of the "X" phase are met. There will be rework and changes to the system as the stakeholders (customers and "A, B, and C" phase personnel) negotiate the acceptance criteria for the final production system[81]. Stakeholder requirements are compared to the capabilities delivered by the systems during Verification and Validation (V&V or acceptance test), and negotiation of the percentage of the final product end-user requirements that are met.

A perfect SE process could ensure that all stakeholders are involved in design and production decisions, and that the capability tradeoffs are acceptable, and understood, by all stakeholders. The integration of different sub-systems can be challenging and a lot of effort will be spent mitigating integration issues. By keeping all informed of the tradespace decision process, the risk of getting to the "D" phase and integrating a product that is not acceptable to either the customer or other stakeholders is greatly reduced.

a. "D" Phase People

The "D" phase people are the leaders from the "A, B, and C" phases that understand the sub-systems and how they will interact when integrated into the whole system. They are determined to make the system work, and will work night and day to achieve successful systems.

[81] Acceptance test criteria should be agreed in earlier phases.

4. “E” Phase—Clean-up

The clean-up phase is the last part of the SE process, before production, where the system manuals (training, maintenance, and operation) are developed, delivered, and training is conducted for the end-users.

As the system proceeds past the delivery phase, production of the item continues (in the “F” phase), as well as operational use (“G” phase), system refinement, upgrades (“H” phase), retirement (“I” phase), and disposal (“J” phase).

a. “E” Phase People

“E” phase people like to “clean-up” the system design by documenting configurations, developing end-user training documents, and cleaning up design issues. These people usually are writers and enjoy developing documentation, for example training documents, etc.

5. “Other” Phases

For systems that have multiple units that are delivered to the customer, there is the continued production of the system (with some delivery timeline).

There is also the operational use of the product (“G”) as well as the maintenance (“H”) and repair to the system. In addition, there is system refinement (“H”), as planned and unplanned, but necessary, upgrades are incorporated into the system design.

There is the planning for system retirement (“I”) and disposal (“J”) used once the system has exceeded its useful life.

a. “Other” Phase People (“F,” “G,” “H,” “I,” “J”)

These people are mostly life-cycle support personnel who carry out production, ensure maintenance, perform upgrades, provide support, and who will plan for retirement, and disposal of the system.

The previous two sections describe the different SE process model. The next section will address the mapping of the generic SE approach to the DoD Acquisition Process.

LIST OF REFERENCES

[1] Department of Defense. *The Implementation of Network-Centric Warfare*. Washington, DC: NASA, 2006.

[2] Department of Defense, "Defense Acquisition Guidebook," Department of Defense, Washington, DC, 2004.2] Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), *The Defense Acquisition System—DoD Directive 5000.01*. Washington, DC: Department of Defense, 12 May 2003.

[3] Department of Defense, "Defense Acquisition Guidebook," Department of Defense, Washington, DC, 2004.

[4] C. Gunderson, "Network-Centric Warfare (NCW): Its Origin and Its Future ... Revisited," (unpublished) pp. 1–12, 2009.

[5] C. Gunderson, O'Neill B. and Macdonald S. "DoD Netcentricity...a buzzword or a business model?" *Software Tech News 9(4) 2008*, p. 22.

[6] A. Cebrowski and J. Garstka, "Network-Centric Warfare: Its origin and future," *U.S. Naval Institute Proceedings*, vol. 124, pp. 28–35, 1998.

[7] Anonymous "Network-Centric Warfare," downloaded 6 May 2009 from http://en.wikipedia.org/wiki/Network-centric_warfare.

[8] J. Garstka, "Network Centric Warfare: An Overview of Emerging Theory," downloaded on 6 May 2009 from http://www.mors.org/publications/phalanx/dec00/feature.htm.

[9] B. Still, *The Role of Leadership in Self-Synchronized Operations—Implications for the U.S. Military*. Newport, RI: US Naval War College, 2003.

[10] J. Tisserand, "Network centric warfare case study: U.S. V corps and 3rd infantry division (mechanized) during Operation Iraqi Freedom combat operations (Mar-Apr 2003). Volume 3. Network centric warfare insights," Army War College, Carlisle Barracks, PA., 2006.

[11] Department of Defense, *Department of Defense Report to Congress on Network Centric Warfare*. 2001.

[12] S. Tzu, *The Art of War*. Boulder: Westview Press, 1994, p. 375.

[13] D. Alberts, J. Garstka and F. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority*. Washington, DC: National Defense University Press, 2002.

[14] Assistant Secretary of Defense (Networks and Information Integration)/Department of Defense Chief Information Office, *Information Assurance (IA)—DoD Directive 8500.01E.* Washington, DC: Department of Defense, 2002, pp. 1–22.

[15] R. Hayes-Roth, *Model-Based Communication Networks and VIRT: Filtering Information by Value to Improve Collaborative Decision-Making.* http://handle.dtic.mil/100.2/ADA464388 ed. Monterey, CA: Naval Postgraduate School, 2005, p. 36.

[16] Department of Defense Joint Chiefs of Staff, *Joint Vision 2020.* Washington, DC: Joint Chiefs of Staff, 2000, p. 36.

[17] Anonymous, "Automated Information System," downloaded on 20 September 2009 from http://en.wikipedia.org/wiki/Automated_information_system.

[18] Department of Defense Chief Information Office, *Vision for a Net-Centric, Service-Oriented DoD Enterprise. Department of Defense Global Information Grid Architectural Vision. Version 1.0.* , http://handle.dtic.mil/100.2/ADA484389 ed. Ft. Belvoir, VA: Defense Technical Information Center, 2007, p. 39.

[19] S. Anderson, "Interview with Rear Adm. William D. Rodriguez, Space and Naval Warfare Systems Command Chief Engineer," *CHIPS*, 2005.

[20] Anonymous, "What is FORCEnet?" Downloaded on 18 May 2009 from http://forcenet.navy.mil/fn-definition.htm.

[21] P. Geren and G. Casey, "A Statement on the Posture of the United States Army 2008," submitted to the Committees and Subcommittees of the United States Senate and House of Representatives, 2d Session, 110th Congress, 26 February 2008.

[22] Anonymous, "Information Papers—LANDWARNET and the Global Information Grid," downloaded on 1 September 2009 from http://www.army.mil/aps/08/information_papers/transform/LANDWARNET_and_the_Global_Information_Grid.html.

[23] J. Luddy, *The Challenge and Promise of Network-Centric Warfare.* Arlington, VA: Lexington Institute, 2005, pp. 1-15. Downloaded on 18 May 2009 from http://www.lexingtoninstitute.org/docs/521.pdf.

[24] Anonymous, “C2 constellation,” downloaded on 1 September 2009 from http://www.globalsecurity.org/military/systems/aircraft/systems/c2-constellation.htm.

[25] N. Sweet, *The C2 Constellation A US Air Force Network Centric Warfare Program—Network Centric Applications and C4ISR Architecture*, presented at the 2004 Command and Control Research and Technology Symposium in Arbor, MI, June 2004.

[26] R. Hayes-Roth, "Valued Information at the Right Time," downloaded on 1 September 2009 from http://groups.google.com/group/w2cog/web/virt?pli=1.

[27] R. Goshorn, "Findings for Network-Centric Systems Engineering Education," presented at the MILCOM:08 Assuring Mission Success Conference in San Diego, CA, November 2008.

[28] J. Patterson, M. Ott and E. Giglio, "When Instructions Provide Too Much Flexibility, Establish Rules Defense Acquisition Performance Assessment Redux: Unpredictability, Uncertainty and Program Failure: Implementing a Rule-set Can Be the Fix," *Proceedings of the Sixth Annual Acquisition Symposium*, vol. II, pp. 262-–80, 22 April 2009.

[29] R. Kadish and G. Abbott, "Defense Acquisition Performance Assessment Report," Office of the Deputy Secretary of Defense, Washington, DC, January 2006.

[30] L. Jones and J. McCaffery, *Budgeting, Financial Management, and Acquisition Reform in the U.S. Department of Defense.* Charlotte, N.C: IAP-Information Age Pub. Inc, 2008, p. 703.

[31] Anonymous, "Robert McNamara," downloaded on 28 May 2009 from http://en.wikipedia.org/wiki/Robert_McNamara.

[32] Anonymous, "Department of Defense," downloaded on 1 September 2009 from http://www.fedaccess.com/dod-00.htm.

[33] Anonymous, "Planning, Programming, Budgeting, and Execution," downloaded on 1 September 2009 from https://acc.dau.mil/GetAttachment.aspx?id=30701&pname=file&lang=en-US &aid=5473.

[34] Anonymous, PowerPoint presentation for Naval Postgraduate School course MN3331 (Advanced Principles of Defense Acquisition and Program Management), "MN3331 Principles of Systems Acquisition: Defense Resource Allocation: Planning, Programming, Budgeting, and Execution (PPBE)."

[35] Deputy Secretary of Defense, "Management initiative decision 913: Implementation of a 2-year planning, programming, budgeting, and execution process," Tech. Rep. MID 913, 22 May 2003.

[36] L. Smith, *Implementation of Management Initiative Decision (Mid) 913–Background and Impact within DOD.* Carlisle Barracks, PA: U.S. Army War College, 2004, p. 24.

[37] Chairman of the Joint Chiefs of Staff, *Joint Capabilities Integration and Development System—CJCS Instruction 3170.01F*. Washington, DC: Joint Chiefs of Staff, 1 May 2007.

[38] Chairman of the Joint Chiefs of Staff. *Charter of the Joint Requirements Oversight Council—CJCS Instruction 5123.01D*. Washington, DC: Joint Chiefs of Staff, 1 August 2007.

[39] Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), *Operation of the Defense Acquisition System—DoD Instruction 5000.02*. Washington, DC: Department of Defense, 2008.

[40] Chairman of the Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council—CJCS Instruction 5123.01A.* Washington, DC: Joint Chiefs of Staff, 8 March 2001.

[41] Anonymous "Joint Requirements Oversight Council," downloaded on 9 June 2009 from http://en.wikipedia.org/wiki/Joint_Requirements_Oversight_Council.

[42] Anonymous, Analysis of Alternatives, downloaded on 25 August 2009 from https://acc.dau.mil/CommunityBrowser.aspx?id=24688.

[43] B. Brown, "DoD Instruction 5000.02 2 December 2008 Operation of the Defense Acquisition System Statutory and Regulatory Changes," downloaded on 1 September 2009 from https://acc.dau.mil/CommunityBrowser.aspx?id=24530.

[44] Anonymous, “Defense Acquisition Board,” downloaded on 25 August 2009 from http://en.wikipedia.org/wiki/Defense_Acquisition_Board.

[45] Director, Systems and Software Engineering and Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). *Systems Engineering Guide for Systems of Systems*. Washington, DC: Department of Defense, August 2008.

[46] Department of Defense, "Defense acquisition guidebook,” downloaded 1 August 2009 from https://acc.dau.mil/dag.

[47] D. M. Buede, *The Engineering Design of Systems Models and Methods*. New York: Wiley, 2000, pp. 462. Downloaded on 1 September 2009 from http://www.knovel.com/knovel2/Toc.jsp?BookID=1410.

[48] R. Goshorn, PowerPoint presentation for Navy Postgraduate School SI 3400 course (Fundamentals of Engineering Project Management), "SI 3400—Fundamentals of Engineering Project Management: Overview of Systems Engineering and Projects (Simplified View)," Naval Postgraduate School, 2009 (unpublished).

[49] C. Gunderson, D. Minton and R. Hayes-Roth. “Value-based acquisition: An objective, success-centric, evolutionary approach,” downloaded on 18 September 2009 from http://w2cog.googlegroups.com/web/Value-Based%20Acquisiton%20ver%20viii%201-11-09.pdf?gda=yjy5t20AAAChEzNuqJ_0KuefNxIlAThF8O7bvQ5ZSDJ97flzqePsKqbbAD-WGQWktJCQkZLGVlgJPiDl_5wYZLeI2tTV03x_54f0lzQ-hfadb9YBBAFsiEc8g1gFspt7rLtYAxyFmO3lNv--OykrTYJH3lVGu2Z5.

[50] Defense Science Board. *DoD Policy and Procedures for Acquisition of Information Technology*. Department of Defense, Washington, DC, 2009.

[51] M. Sullivan, "Defense acquisitions DOD must prioritize its weapon system acquisitions and balance them with available resources,” testimony before the Committee on the Budget, House of Representatives, 2009.

[52] B. Arbetter, "USD(I) R&D and Technology Transition," PowerPoint presentation downloaded on 30 June 2009 from www.dia.mil/AE_conf09/R&D_and_Technology_Transition.ppt.

[53] General Services Administration, Department of Defense and National Aeronautics and Space Administration, *Federal Acquisition Regulations* , vol. 1, Washington, DC: U.S. Government Accountability Office, 2005, pp. 1–1130.

[54] Department of Defense, "Defense federal acquisition regulation supplement (DFARS)," Washington, DC: Department of Defense, 2007, pp. 1–71.

[55] Anonymous, "Net-Ready Key Performance Parameter (KPP)," downloaded on 19 August 2009 from https://acc.dau.mil/CommunityBrowser.aspx?id=28974.

[56] C. Gunderson, D. Minton and R. Hayes-Roth. *Objective, value-based, rapid, evolutionary, acquisition process for information system-of-systems*. 2008, pp. 1–30 (unpublished).

[57] C. Gunderson, "Sustainment and Net-Ready Key Performance Parameters in a Value-Based (Evolutionary Information System) Acquisition Framework (VAF)," (unpublished) pp. 1–24, 2009.

[58] Assistant Secretary of Defense (Networks and Information Integration)/Department of Defense Chief Information Office, *Data sharing in a Net-Centric Department of Defense—ASD(NII)/DoD CIO Directive 8320.02*, Washington, DC: Department of Defense, 2004.

[59] Anonymous, "Application Programming Interface (API)," downloaded on 2 September 2009 from http://en.wikipedia.org/wiki/Application_programming_interface.

[60] Anonymous, "Consumer Reports," downloaded on 2 September 2009 from http://en.wikipedia.org/wiki/Consumer_Reports.

[61] Anonymous, "List of System Quality Attributes," downloaded on 2 September 2009 from http://en.wikipedia.org/wiki/List_of_system_quality_attributes.

[62] R. Lefande, "Network-centric Acquisition—The key to joint warfighting." *PM (March-April)*, 2002, p. 84.

[63] Anonymous, "Net-Centric Enterprise Services (NCSE)," downloaded on 2 September 2009 from http://www.disa.mil/nces/index.html.

[64] J. Johnson and C. Blais, "Ontology-based Solutions for Software Reuse," *Proceedings of the Sixth Annual Acquisition Symposium*, vol. II, pp. 77-90, 22 April 2009.

[65] Anonymous "Government Off-The-Shelf," downloaded on 21 August 2009 from http://en.wikipedia.org/wiki/Government_off-the-shelf.

[66] Anonymous "Modular Open System Approach (MOSA)," downloaded on 11 August 2009 from http://www.acq.osd.mil/sse/initiatives/init_mosa.html.

[67] Defense Acquisition University, *Modular Open Systems Approach (MOSA) Continuous Learning (CL) Module CLE 013.* Ft. Belvoir, VA: Defense Acquisition University, 2009, downloaded on 1 September 2009 from http://icatalog.dau.mil/onlinecatalog/courses.aspx?crs_id=420.

[68] J. Brock, *Testimony before the Subcommittee on Technology and Procurement Policy, Committee on Government Reform, House of Representatives—INTELLECTUAL PROPERTY Industry and Agency Concerns Over Intellectual Property Rights.* Washington, DC: Government Accountability Office, 2002, p. 13.

[69] G. Tereschuk, "Government Purpose Rights in Technical Data and Computer Software in DOD Acquisition," downloaded on 1 September 29 from http://www.wifcon.com/analysis.htm.

[70] G. Miller, PowerPoint presentation for Navy Postgraduate School SE 3121 course (Intro to C4ISR), "Network-Centric Warfare—IME Rings," 2008.

[71] Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), *Department of Defense Guide to Integrated Product and Process Development (Version 1.0).* Washington, DC: Department of Defense, 1998.

[72] D. M. Buede, *The Engineering Design of Systems Models and Methods*. New York: Wiley, 2000, pp. 462. Downloaded on 1 September 2009 from http://www.knovel.com/knovel2/Toc.jsp?BookID=1410.

[73] B. S. Blanchard, W. J. Fabrycky and Joint Author, *Systems Engineering and Analysis.* Englewood Cliffs, NJ: Prentice-Hall, 1981, p. 703.

[74] R. Goshorn, PowerPoint presentation for Navy Postgraduate School SI 3400 course (Fundamentals of Engineering Project Management), "SI 3400—Fundamentals of Engineering Project Management: Overview of Systems Engineering and Projects (Simplified View)," Naval Postgraduate School, 2009 (unpublished).

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